Welfare of cattle during killing for purposes other than slaughter

EFSA Panel on Animal Health and Welfare (AHAW)

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Welfare of cattle during killing for purposes other than slaughter

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Abstract

Cattle of different ages may have to be killed on farm for purposes other than slaughter (the latter being defined as killing for human consumption) either individually or on a large scale, e.g. for economic reasons or for disease control. The purpose of this scientific opinion is to assess the risks associated with the on-farm killing of cattle. The processes during on-farm killing that were assessed included handling and moving, stunning and/or killing methods (including restraint). The killing methods were grouped into mechanical and electrical methods as well as lethal injection. In total, 21 hazards compromising animal welfare were identified and characterised, most of these related to stunning and/or killing. Staff was identified as an origin for all hazards, either due to lack of appropriate skills needed to perform tasks or due to fatigue. Possible preventive and corrective measures were assessed: measures to correct hazards were identified for 19 hazards, and the staff was shown to have a crucial role in prevention. Three welfare consequences of hazards to which cattle can be exposed during on-farm killing were identified: impeded movement, pain and fear. The welfare consequences and relevant animal-based measures related to these were described. Outcome tables linking hazards, welfare consequences, animal-based measures, origins of the hazards, preventive and corrective measures were developed for each process. Mitigation measures to minimise the welfare consequences are proposed.

Keywords: cattle, bison, buffalo, on-farm killing, hazards, animal welfare consequences, animal-based measures, preventive and corrective measures

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Summary

In 2009, the European Union (EU) adopted Council Regulation (EC) No. 1099/2009 'on the protection of animals at the time of killing', which was prepared on the basis of two scientific opinions adopted by the European Food Safety Authority (EFSA) in 2004 and 2006. In 2013, EFSA produced another scientific opinion related to this subject.

In parallel, since 2005, the World Organisation for Animal Health (OIE) has developed two chapters in its Terrestrial Animal Health Code: (i) Slaughter of animals (Chapter 7.5), (ii) Killing of animals for disease control purposes (Chapter 7.6). OIE has created an ad hoc working group to revise these two chapters.

Against this background, the European Commission requested EFSA to develop a scientific opinion providing an independent view on the killing of cattle for purposes other than slaughter (the latter being defined as killing animals for human consumption), which includes: (i) large-scale killings for disease control and for other situations, like environmental disaster management; and (ii) on-farm individual killing of animals that are injured or terminally ill to end pain and suffering due to the lack of treatment options.

With specific reference to handling and moving, restraint and killing, EFSA was asked to: identify the animal welfare hazards present during on-farm killing and their possible origins in terms of facilities/equipment and staff [Term of Reference (ToR) 1]; define qualitative or measurable criteria to assess performance on animal welfare [animal-based measures (ABMs) (ToR2); provide preventive and corrective measures (structural or managerial) to address the hazards identified (ToR3); and point out specific hazards related to species or types of animals (e.g. buffaloes; ToR4). The European Commission also asked EFSA to provide measures to mitigate the welfare consequences that can be caused by the identified hazards. This scientific opinion aims to update the above-reported EFSA outputs by reviewing the most recent scientific publications and providing the European Commission with a sound scientific basis for future discussions at international level on the welfare of animals in the context of killing for purposes other than slaughter.

The mandate also requested a list of unacceptable methods, procedures or practices that need to be analysed in terms of the above welfare aspects. It has to be noted that methods, procedures or practices cannot be subjected to a risk assessment procedure if there is no published scientific evidence related to them. Chapter 7.5.10 of the OIE Terrestrial Animal Health Code includes a list of several unacceptable practices and the Panel agrees with this list. In addition, the Panel listed some practices that lead to serious welfare concerns during the on-farm killing of cattle. These practices should be avoided, redesigned or replaced by other practices, leading to better welfare outcomes. Finally, the Panel provided a list of methods that are highly painful and should never be used on welfare grounds. To address the mandate, two main approaches have been used to develop this scientific opinion: i) literature search; followed by ii) expert opinion through Working Group (WG) discussion. The literature search was carried out to identify peer-reviewed scientific evidence providing information on the aspects requested by the ToRs (i.e. description of the processes, and identification of welfare hazards, their origin, preventive and corrective measures, welfare consequences and related animal-based measures). From the available literature and their own knowledge, the WG experts identified the processes that should be included in the assessment and produced a list of the possible welfare hazards present during each process related to on-farm killing of cattle. To address the ToRs, the experts identified the origin of each hazard (ToR-1) and related preventive and corrective measures (ToR-3), along with the possible welfare consequences of the hazards and relevant animal-based measures (ToR-2). Measures to mitigate the welfare consequences were also considered. Specific hazards were identified in relation to particular types of animals (ToR-4), for example, the thick skull of buffaloes and bisons requiring adapted mechanical methods. In addition, an uncertainty analysis on the hazard identification process was carried out, limited to quantifying the probability of wrongly omitting true hazards (i.e. false negatives) or wrongly including non-hazards (false positives) in the assessment. The processes assessed in this scientific opinion are handling/moving and killing. The description of the restraint, when needed, has been included in the assessment of the relevant killing methods. As this scientific opinion will be used by the European Commission to address the OIE standards, more killing methods than those reported in Council Regulation (EC) No 1099/2009 have been considered. However, among the methods that are used worldwide, the following criteria for the selection of those included in this assessment have been applied: a) all methods with described technical specifications known to the experts, not only those described in Council Regulation (EC) No. 1099/2009, and b) methods currently used for killing of cattle as well as those still in development

but likely to become commercially applicable and c) methods for which the welfare aspects (in terms of welfare hazards, welfare consequences, ABMs, preventive and corrective measures) are described sufficiently in the scientific literature. Applying these criteria, some methods that may be applied worldwide have not been included in the current assessment.

The killing methods that have been identified as relevant for cattle can be grouped into three categories: (1) mechanical, (2) electrical and (3) lethal injection.

Mechanical methods include penetrative captive bolt followed by a killing method (pithing, sticking or lethal injection), non-penetrative captive bolt followed by a killing method and firearm with free projectile. In the electrical killing methods, head-only electrical stunning is followed (or applied at the same time) by application of the electrical current across the chest to span the heart. Lethal injection involves injection of overdose of anaesthetic drugs that cause rapid loss of consciousness followed by death.

In response to ToR-2, three welfare consequences that cattle may experience during on-farm killing have been identified: impeded movement, pain and fear. ABMs for the assessment of these welfare consequences have subsequently been identified.

In the killing phase, cattle may experience welfare consequences if hazards occur during restraint (before killing method application), or if killing is ineffective. Since consciousness is a prerequisite to experience pain and fear during killing, the ABMs of the state of consciousness are assessed during the killing process to identify the possibility that cattle experience pain and fear. These ABMs of the state of consciousness are specific to the killing methods and some of them were proposed in a previous EFSA opinion (EFSA AHAW Panel, 2013). Flowcharts, including ABMs of the state of consciousness to be used for monitoring of killing efficacy, are reproduced in this scientific opinion in order to provide the European Commission with the full welfare assessment at killing.

In answering ToR-1, 21 related hazards having welfare consequences were identified. All the processes described in this scientific opinion have hazards. The main hazards are associated with lack of staff skills and training, and poorly designed facilities or badly maintained equipment. Animal welfare consequences can be the result of one or more hazards. Exposure to multiple hazards has a cumulative effect on the welfare consequences (e.g. pain due to injury caused during handling and moving will lead to more severe pain during killing). Some hazards are inherent to the killing method and cannot be avoided (e.g. restraining), other hazards originate from suboptimal application of the method, mainly due to unskilled staff (e.g. inappropriate handling, use of wrong parameters e.g. for electrical methods). In fact, staff was identified as one of the origins for all the hazards, in particular related to lack of appropriate skill sets needed to perform the moving and handling, restraining and killing or to fatigue.

The uncertainty analysis on the set of hazards provided for each process in this scientific opinion revealed that the experts were 95–99% certain that all listed hazards may occur during killing of cattle. However, the experts were 95–99% certain that at least one welfare hazard was missing in their assessment. This is due to the lack of documented evidence on all possible variations in the processes and methods being practised worldwide (see Interpretation of ToRs on the criteria for selection of killing methods to be included).

In response to ToR-3, preventive and corrective measures for the identified hazards have been identified and described. Some measures apply for a specific hazard; others can apply to multiple hazards (e.g. staff training). For all the hazards, preventive measures can be put in place with management having a crucial role in prevention. Corrective measures were identified for 19 hazards; when they are not available or feasible to put in place, actions to mitigate the welfare consequences caused by the identified hazards should be put in place.

Outcome tables summarising all the mentioned elements requested by the ToRs (identification of welfare hazards, origin, preventive and corrective measures, welfare consequences and related ABMs) have been produced for each process and killing method to provide an overall outcome, where all retrieved information is presented concisely. Conclusions and recommendations subdivided by phase and specific killing method are provided. To spare cattle from severe welfare consequences, a standard operating procedure (SOP) should include identification of hazards and related welfare consequences using relevant ABMs, as well as preventive and corrective measures at each phase of killing. Training of staff is a key preventive measure to avoid hazards and mitigate welfare consequences. All processes of the killing should be carried out by trained and skilled personnel. Ideally, cattle should be killed in their home pens and carcasses moved for disposal. If movement of cattle is required, the distance from the home pens to the point of killing should be kept to a minimum and the animals should be moved gently. Painful stimuli, such as electric goads, hitting with a stick etc. must be avoided. Instead, passive stimuli such as flags and paddles should be used. To monitor the efficacy of the killing method, the state of consciousness and death of the animals should be checked at each step – i.e. after stunning, after the application of a killing procedure and before carcass disposal – using the suggested ABMs.

Finally, in response of ToR-4 specific hazards and preventive measures are presented for pregnant cows, extensively raised animals, breeding bulls, buffaloes and bison.

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1. Introduction

1.1. Background and Terms of Reference as provided by the requestor

1.1.1. Background

The European Union adopted in 2009 Council Regulation (EC) No 1099/2009[1] *on the protection of animals at the time of killing*. This piece of legislation was prepared on the basis of two EFSA scientific opinions respectively adopted in 2004[2] and 2006.[3] The EFSA provided additional scientific opinions related to this subject in 2012,[4] 2013[5,6,7,8,9,10] 2014[11,12] 2015[13] and 2017.[14,15]

In parallel, since 2005, the World Organisation for Animal Health (OIE) has developed in its Terrestrial Animal Health Code two chapters covering a similar scope:

- Slaughter of animals (Chapter 7.5)
- Killing of animals for disease control purposes (Chapter 7.6)

The chapter slaughter of animals covers the following species: cattle, buffalo, bison, sheep, goats, camelids, deer, horses, pigs, ratites, rabbits and poultry (domestic birds as defined by the OIE).

The OIE has created an ad hoc working group with the view to revise the two chapters.

Against this background, the Commission would like to request the EFSA to review the scientific publications provided and possibly other sources to provide a sound scientific basis for the future discussions at international level on the welfare of animals in the context of slaughter (i.e. killing animals for human consumption) or other types of killing (killing for other purposes than slaughter).

Terms of Reference

The Commission therefore considers it opportune to request EFSA to give an independent view on the killing of animals for other purposes than slaughter:

- free moving animals (cattle, buffalo, bison, sheep, goats, camelids, deer, horses, pigs, ratites)
- animals transported in crates or containers (i.e. rabbits and domestic birds).

The request focuses on the cases of large scale killing which take place in case of depopulation for disease control purposes and for other similar situations (environmental contamination, disaster management, etc.) outside slaughterhouses.

The request also considers in a separate section the killing of unproductive animals that might be practiced on-farm (day-old chicks, piglets, pullets, etc.)

The request includes the following issues:

- handling,
- restraint,
- stunning/killing,
- unacceptable methods, procedures or practices on welfare grounds.

For each process or issue in each category (i.e. free moving/in crates or containers), EFSA will:

[1] OJ L 303, 18.11.2009, p. 1.
[2] The welfare aspects of the main systems of stunning and killing the main commercial species of animals. EFSA Journal 2004;45, pp. 1–29.
[3] The welfare aspects of the main systems of stunning and killing applied to commercially farmed deer, goats, rabbits, ostriches, ducks, geese and quail. EFSA Journal 2006; 326, pp. 1–18.
[4] Electrical requirements for waterbath equipment applicable for poultry. EFSA Journal 2012;10(6):2757.
[5] Electrical parameters for the stunning of lambs and kid goats. EFSA Journal 2013;11(6):3249.
[6] Monitoring procedures at slaughterhouses for bovines. EFSA Journal 2013;11(12):3460.
[7] Monitoring procedures at slaughterhouses for pigs. EFSA Journal 2013;11(12):3523.
[8] Monitoring procedures at slaughterhouses for poultry. EFSA Journal 2013;11(12):3521.
[9] Monitoring procedures at slaughterhouses for sheep and goats. EFSA Journal 2013;11(12):3522.
[10] The use of carbon dioxide for stunning rabbits. EFSA Journal 2013;11(6):3250.
[11] The use of low atmosphere pressure system (LAPS) for stunning poultry. EFSA Journal 2014;12(1):3488.
[12] Electrical requirements for poultry waterbath stunning equipment. EFSA Journal 2014;12(7):3745.
[13] The scientific assessment of studies on electrical parameters for stunning of small ruminants (ovine and caprine species). EFSA Journal 2015;13(2):4023.
[14] The low atmospheric pressure system for stunning broiler chickens. EFSA Journal 2017;15(12):5056.
[15] The animal welfare aspects in respect of the slaughter or killing of pregnant livestock animals (cattle, pigs, sheep, goats, horses). EFSA Journal 2017;15(5):4782.

– Identify the animal welfare hazards and their possible origins (facilities/equipment, staff),
– Define qualitative or measurable criteria to assess performance on animal welfare (ABMs),
– Provide preventive and corrective measures to address the hazards identified (through structural or managerial measures),
– Point out specific hazards related to species or types of animals (young, with horns, etc.).

1.2. Interpretation of the Terms of Reference

This scientific opinion concerns the killing of cattle including buffaloes and bison for purposes other than slaughter. A separate scientific opinion, which deals with welfare of cattle at slaughter (EFSA AHAW Panel, 2020), is referred to in the present document.

The European Commission asked EFSA to provide an independent view on the welfare of cattle during on-farm killing for purposes other than slaughter, which takes place during the following scenarios: a) large-scale killings (depopulation for disease control purposes and for other similar situations, such as environmental contamination, disaster management etc.) outside the slaughterhouses, and b) individual on-farm killing of unproductive animals. The Panel agreed to include in this latter category the animals that are injured or terminally ill. For each of these scenarios, several welfare aspects need to be analysed (including e.g. welfare hazards, hazard origins, animal-based measures and corrective measures).

This scientific opinion will use definitions related to the killing of cattle provided by the Council Regulation (EC) No 1099/2009 of 24 September 2009 on the protection of animals at the time of killing, which entered into force in January 2013. In this scientific opinion killing refers to any intentionally applied procedure that causes death of the animal. The processes involved in this operation are (1) handling and moving and (2) killing methods.

Considering that the restraint of cattle prior to killing (including stunning if a stunning method is applied before killing the cattle) varies depending on the killing method, the restraint will be included in the assessment of the relevant killing method. The main methods relevant for cattle identified can be grouped in three categories: (1) mechanical, (2) electrical and (3) lethal injection.

The mandate requests EFSA to identify hazards at the different phases ('Handling/moving', 'Killing') of killing for other purposes than slaughter and their relevant origins in terms of equipment/facilities or staff (ToR-1). Due to the diversity of available killing methods, in this scientific opinion, the assessment of hazards, welfare consequences and related ABMs, hazards' origin and preventive/corrective actions will be dealt with separately for each method. Mitigation measures to minimise animal welfare consequences are also described.

The mandate also asks to define qualitative or measurable (quantitative) criteria to assess performance on animal welfare (ABMs; ToR-2). This ToR has been addressed by identifying and describing the negative consequences on the welfare (so-called 'welfare consequences') occurring to the cattle due to the identified hazards and the relevant ABMs that can be used to assess qualitatively and/or quantitatively the welfare consequences.

A ranking of the identified hazards in terms of severity, magnitude and frequency of the welfare consequences that they can cause would have been useful to prioritise actions and improve the procedure of the on-farm killing; however, this has not been performed due to the limited time for this mandate.

This scientific opinion will also propose preventive and corrective measures for the identified hazards; these measures will refer to two main categories: 1) equipment and 2) managerial (ToR3). When corrective measures for the hazards are not available or feasible, actions to mitigate the welfare consequences caused by the identified hazards are discussed. In addition, it has been assessed whether specific categories of cattle or minority species related to cattle such as buffaloes might be subjected to specific hazards (ToR-4).

Among the methods that are used worldwide for on-farm killing, EFSA has applied the following criteria for the selection of stunning and killing methods to be included in this assessment:

a) all methods with described technical specifications known by the experts and not only the methods described in Council Regulation (EC) No 1099/2009, and
b) methods currently used for killing of cattle, and those which are still under development but are likely to become commercially applicable, and
c) methods for which the welfare aspects (in terms of welfare hazards, welfare consequences, ABMs, preventive and corrective measures) are described sufficiently in the scientific literature.

Applying these criteria will result in not including nor describing in this scientific opinion some practices, which may be applied worldwide.

The mandate also requests a list of methods, procedures or practices deemed unacceptable on welfare grounds. Regarding this request, the Panel is aware of two issues. Firstly, it has to be noted that some methods, procedures or practices under question cannot be subjected to a risk assessment procedure, because there is no published scientific evidence relating to them. Secondly, although scientific risk assessment can support discussions on what practices are acceptable or unacceptable on welfare grounds, the ultimate decisions on acceptability involve e.g. ethical and socioeconomic considerations that need to be weighed by the risk managers.

In response to this request, therefore, the Panel listed practices for which welfare consequences were identified and classified as 'severe'. To do so, expert knowledge was elicited, and the available scientific evidence was assessed in order to subdivide practices into two groups, namely the group of those leading to 'severe' welfare consequences and the group of those not leading to 'severe' welfare consequences. For the practices leading to severe welfare consequences, the Panel identified serious welfare concerns and therefore recommends that these practices should be avoided, redesigned or replaced by other practices, leading to better welfare outcomes. These practices are discussed in this scientific opinion.

2. Data and methodologies

2.1. Data

2.1.1. Data from literature

Information from the papers selected as relevant from the literature search (LS) described in Section 2.2.1 and from additional literature identified by the WG experts was used for a narrative description and assessment to address ToRs 1, 2, 3 and 4 (see relevant sections in the Assessment section).

2.1.2. Data from expert opinion

The data obtained from the literature were complemented by WG experts' opinion in order to identify hazards' origins, welfare consequences, ABMs and preventive and corrective measures relevant for the current assessment.

2.2. Methodologies

Two main approaches were used to develop this scientific opinion: (i) literature search and (ii) expert opinion through WG discussion.

The general principle adopted was that, when scientific literature supporting the text is available, the relevant reference/s are cited in the body of the document. When no published information is available, expert opinion was used.

2.2.1. Literature search

A literature search was carried out to identify hazards related to animal welfare during on-farm killing of cattle in peer-reviewed and grey literature.

Restrictions were applied in relation to the date of publication, considering only those records published after a previous EFSA scientific opinion on the topic (EFSA, 2004).

A total of 20 references were retrieved and reviewed by the WG members until a final subset of seven relevant references was selected and considered in this assessment by reviewing the full papers.

Full details of the literature search protocol, strategies and results, including the number of the records that underpin each process, are provided in Appendix A to this scientific opinion. In addition, the experts in the WG selected relevant references starting from scientific papers, including review papers, books chapters and non peer-reviewed papers known by the experts themselves or retrieved through non-systematic searches, until the information of the subject was considered sufficient to undertake the assessment. When needed, relevant publications before 2004 were considered.

2.2.2. Risk assessment methodology and structure of the scientific opinion

The working group experts followed the risk assessment methodology from the EFSA's guidance on risk assessment in animal welfare (EFSA AHAW Panel, 2012b).

Based on expert opinion through working group discussion, the WG experts firstly described the phases and the related processes of killing on farm and specifically which killing methods should be considered for the current assessment.

Using the available literature and their own knowledge, the experts then produced a list containing the possible welfare consequences characterising each process related to the on-farm killing of cattle. To address the ToRs, the experts then identified the hazards leading to those welfare consequences and their origin (ToR-1) and the related preventive and corrective measures (ToR-3); this was also done for specific animals categories (ToR-4). ABMs for measuring the welfare consequences were identified (ToR-2). Measures to mitigate the welfare consequences were also considered.

It should be noted that ToR-1 of the mandate asks to identify the origins of the hazards in terms of staff or facilities/equipment. When discussing the origins, it was considered necessary to explain them further by detailing what actions of the staff or features of the equipment and premises that can cause the hazard. Therefore, for each origin category (staff, premises/equipment), relevant origin specifications have been identified by expert opinion.

Related to the structure of the scientific opinion, chapters are organised by Phase 1 'Handling and moving' and Phase 2 'Killing' (i.e. restraining and application of stunning and killing method). In Phase 1, welfare consequences and hazards are presented in a list for the process 'Handling and moving' and hazards are included within the related welfare consequences. Within Phase 2, subchapters are organised by killing methods and welfare consequences are common for all stunning methods. Instead, hazards are specifically listed within each stunning method.

2.2.3. Development of outcome tables to answer the ToRs

The main results of the current assessment are summarised in tables (so-called outcome tables, see Figure 1 below).

The outcome tables link all the mentioned elements requested by ToRs 1, 2 and 3 of the mandate and provide an overall outcome for each process of killing in which all retrieved information is presented concisely (see description of the structure below and, for details, the specific Outcome Tables at the end of each process). Conclusions and recommendations of this scientific opinion are mainly based on the outcome tables.

The outcome tables have the following structure and the following terminology should be referred to:

- 'OUTCOME TABLE': Each table represents the summarised information for the processes described in the assessment (see at the end of the Chapter dedicated to each process; Section 3.1, Assessment).
- 'HAZARD': the first column in each table, the first column reports all hazards pertaining to the specific process related to on-farm killing of cattle; the number of the section where each hazard is described in detail is reported in brackets. For each hazard, the individual row represents the summarised information relevant to the elements analysed for that hazard. Therefore, it links between an identified hazard, the relevant welfare consequences, origin/s of hazards and preventive and corrective measures (see example in Figure 1).
- 'WELFARE CONSEQUENCES OCCURRING TO THE CATTLE DUE TO THE HAZARD': this column lists the welfare consequences to the cattle of the mentioned hazards.
- HAZARD ORIGIN: this column contains the information related to the category of hazard origin, which can be staff-, equipment- or facility-related. Most hazards can have more than one origin. HAZARD ORIGIN SPECIFICATION: this column further specifies the origin of the hazard namely, what actions of the staff or features of the equipment and facilities can cause the hazard. This information is needed to understand and choose among the preventive and corrective measures.
- PREVENTIVE MEASURE/S OF THE HAZARD: depending on the hazard, origin/s several measures to prevent the hazard are proposed. They are also elements for implementing SOP.
- CORRECTIVE MEASURE/S OF THE HAZARD: in this column practical actions/measures for correction of the mentioned hazard are proposed. These actions relate to the identified origin of the hazards.

- ANIMAL-BASED MEASURES: the bottom row lists the feasible measures to be performed on the cattle to assess the welfare consequences of a hazard.

Hazard	Welfare consequence/s occurring to cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measure/s for the hazard (implementation of SOP)	Corrective measure/s for the hazard
(Number of section)					
ABMs: to assess the identified welfare consequences					

Figure 1: Example of the structure of an outcome table

2.2.4. Uncertainty analysis

The outcome tables include qualitative information on the hazards and related elements identified through the methodologies are explained in Section 2.2.3.

When considering the outcome tables, uncertainty exists at two levels: (i) related to the completeness of the information presented in the table, namely to the number of rows within a table (i.e. hazard identification) and (ii) related to the information presented within a row of the table (i.e. completeness of hazard origins, preventive and corrective measures on the one side, and welfare consequences and ABMs on the other side).

However, owing to the limited time available to develop this scientific opinion, an uncertainty analysis for the latter level was not be conducted, but only for the first level, i.e. for the hazard identification process.

In such a process of hazard identification, uncertainties may result in false-negative or false-positive hazard identifications:

- Incompleteness (false negative): Some relevant welfare related hazards may be missed in the identification process, and so will be considered non-existent or not relevant.
- Misclassified (false-positive): Some welfare-related hazards may be wrongly included in the list of hazards of an outcome table without being a relevant hazard.

Incompleteness (false negatives) can lead to under-estimation of the hazards with a potential to cause (negative) welfare consequences.

The uncertainty analysis was limited to the quantification of the probability of occurrence of false-negative or false-positive hazards. Uncertainty regarding probability of occurrence of false-negative hazards can relate to (i) the situation under assessment i.e. limited to the on-farm killing practices considered in this assessment according to the three criteria described in the Interpretation of ToRs (see Section 1.2) or (ii) the global situation i.e. including all possible variations to the on-farm killing practices that are employed in the world, and that might be unknown to the experts of the WG. The Panel agreed it was relevant to distinguish the false-negative hazard identification analysis for these two cases.

For false-negative hazard identification, the experts elicited the probability that at least one hazard was missed in the outcome table. For false-positive hazard identification, the experts elicited the probability that each hazard included in the outcome table was correctly included (i.e. it was a 'true positive' hazard).

For the elicitation, the experts used the approximate probability scale (see Table 1) proposed in the EFSA uncertainty guidance (EFSA, 2019). Individual answers were then discussed, and a consensus judgement was elicited.

Table 1: Approximate probability scale (see EFSA, 2019, Table 4)

Probability term	Subjective probability range	Additional options	
Almost certain	99–100%	More likely than not: > 50%	Unable to give any probability: range is 0–100% Report as 'inconclusive' cannot conclude, or 'unknown'
Extremely likely	95–99%		
Very likely	90–95%		
Likely	66–90%		
About as likely as not	33–66%		
Unlikely	10–33%		
Very unlikely	5–10%		
Extremely unlikely	1–5%		
Almost impossible	0–1%		

3. Assessment

3.1. Introduction to on-farm killing practices

There are several reasons for killing cattle on farms for other purposes than slaughter (i.e. killing cattle for human consumption). Two main categories can be identified: large-scale killing (or depopulation) and killing individual animals or small groups (euthanasia or emergency killing). On-farm conditions differ from regular slaughterhouses, especially during the killing for disease control reasons due to lack of handling and restraining facilities for the purpose. This also implies that various killing methods on farms may not always be as efficient as in slaughterhouses. Additionally, when it concerns infectious diseases control, the required speed of action places extra pressure on personnel (Gerritzen and Raj, 2009). Contrary to the killing of poultry or pigs, all available killing methods are individual, and there is no existing method for killing of groups of cattle on-farm.

AVMA (2020) recommends the following methods for on-farm killing of cattle: barbiturates and barbituric acid derivatives, firearms, penetrative captive bolt and non-penetrative captive bolts (for calves only). The outcome of the main killing methods applied on-farm can be achieved by a two-step process involving application of a stunning method immediately followed by a killing procedure, or by application of a one-step killing method (Table 2). At the present time, an adjunctive method such as exsanguination, pithing or the lethal injection of a saturated solution of potassium chloride is recommended to ensure death when penetrative captive bolt stunning or another reversible stunning method is used.

Table 2: Methods used for on-farm killing of cattle and animal categories

Method	Animal category
Penetrative captive bolt followed by killing method (two steps)	All
Non-penetrative captive bolt followed by killing method (two steps)	Calves up to 3 months
Firearm (one step)	All
Lethal injection (one step)	All
Electrocution (head-only stunning immediately followed by cardiac arrest with a second current cycle or bleeding) (two steps)	All

3.1.1. Large-scale killing of cattle: main reasons and planning of killing

Large-scale killing on farm or depopulation of cattle may be necessary for several reasons: for the control or eradication of certain animal diseases, to deal with a natural disaster situation such as flood, storm, fire, severe drought and earthquake, as an emergency intervention during feed contamination, as an economic mitigation measure during oversupply or closed marketing channel, foreclosure of the farm, outbreak of a highly contagious disease among human population and, as a consequence, closure of slaughterhouses or movement restriction (e.g. SARS, COVID-19), or to decrease the risk of a zoonotic disease infecting humans (FAWC, 2012).

Indeed, contingency plans exist in most countries to deal with disease outbreaks (e.g. AUSVETPLAN, 2015; DEFRA, 2019), but they do not necessarily include natural disasters such as floods. Nevertheless, Gavinelli et al. (2014) have suggested scenario planning, which is a method of preparing for plausible future events during an outbreak, that allows planners to anticipate the problems, re-evaluate their assumptions and reflect on the consequences of alternatives when developing more resilient strategies. Gavinelli et al. (2014) have suggested considering animal welfare impacts during scenario planning to include, among other aspects of leadership and decision making, animal housing and farming environments, availability of killing methods and competent personnel.

In addition, Gavinelli et al. (2014) have suggested that when preparing the on-farm plan, planners must ensure that it is important to assess the farm, in particular size and location, the species and age of animals, available handling facilities, accessibility of the farm and pens and potential obstructions. When choosing the killing method, key considerations are its capacity to kill the animals in a timely and controlled manner, its compatibility with restraint facilities, location on farm where it is being used and required services (e.g. electrical supply).

It is also important to ensure neonatal, sick and infirm animals are prioritised, restrained individually and killed *in situ*; animals likely to harm each other should be penned separately; and normal husbandry and feeding should continue up to the point of killing (Gavinelli et al., 2014).

3.1.2. Reasons for killing of individuals or of a small number of animals

Individual or small groups of cattle may have to be killed to end pain and suffering due to the lack of treatment options. Additionally, animals may be killed due to the likelihood of suffering in the immediate future and where remedial care is not considered possible or appropriate. The term euthanasia is also used in literature (e.g. FAWC, 2018; AVMA, 2020) to describe the act of inducing death using a method that causes a rapid and irreversible loss of consciousness and death with minimum pain and distress to the animal (OIE, 2018). In this scientific opinion, however, the term killing is used throughout.

In some countries, newborn male dairy calves may also be killed for economic reasons (Hötzel et al., 2014; Cuttance et al., 2017; Renaud et al., 2017).

3.2. Phase 1 – Handling and moving of cattle

Handling is the process of preparation of the animals for the killing, and sometimes, it involves moving the animals to the killing point. Gavinelli et al., 2014 lists animal handling among one of the key stages for monitoring on farm killing.

Handling and moving can be very stressful to cattle, especially when they are isolated out of their home pens. Animals that are sick or injured have difficulties to walk by themselves and should only be moved when there is no other option and with enough support to avoid suffering. Preferably, these animals should be killed in or close to their home pen. Also, for other reasons, like disease control depopulation, moving animals from their home pen should be avoided if possible to limit the spread of the pathogenic agent. Before animals are killed in their home pens, it should be assured that carcass removal for disposal is possible since removal of dead animals out of the home pens can be challenging (especially if large). When it is necessary to move animals to a killing area, they should only be moved from their home pens to the killing pen/point if it can be ensured that they will be killed without any delay.

Farm races are usually designed to handle adult cattle (see Figure 2), but these may be unsuitable for young calves.

When cattle have to be moved, handlers need to understand their behaviour; this will help to prevent pain (injuries) and fear in both animals and people. Cattle are a prey species, and fear motivates them to escape from perceived danger such as human handling (Moran and Doyle, 2015). When they become agitated during handling it is usually due to fear (see Section 3.2.2 for details). Fear-based behaviour is likely to be the main cause of accidents due to cattle becoming agitated or refusing to move (Grandin, 1999). Some major causes of animal handling accidents according to Grandin (1999) are: (i) fearful, agitated animals; (ii) faulty equipment; (iii) male dominance aggression and (iv) maternal aggression.

Cattle should be moved as calmly as possible and allowed to progress freely together. Distractions causing them to baulk must be removed, and the destination pen should be sufficiently lit to attract them towards it (Gavinelli et al., 2014). It is preferable to move cattle in groups as they are gregarious animals. Pens, passageways and races shall be designed and constructed to allow the animals to move freely in the required direction using their behavioural characteristics and without distraction.

The behaviour of the animal handler has a crucial effect on cattle behaviour in this phase and on their welfare. A survey conducted by researchers at Oklahoma State University indicated that 50% of accidents when handling cattle were caused by human mistakes (Huhnke et al., 1997). Cattle should be handled quietly and firmly, using a plastic paddle, flags or streamers (affixed to long handles) to prevent the animals from turning back. Slapping and shouting cause agitation, sudden movements, baulking and panic. Electric goads should not be used (Grandin, 1999). Calm handling in an environment that has been designed with the cattle's perception of the world in mind will be less stressful to the cattle handler as well as to the animals (Grandin, 1999).

For example, cattle are more sensitive to high-pitched sounds than people. The auditory sensitivity of cattle is greatest at 8 kHz, and the human ear is most sensitive at 100 Hz–3 kHz (Grandin, 1999). That means that noise should be avoided as much as possible since, even if it appears not frightening to humans, it can be for animals. This is specifically the case for high-pitched sounds (Grandin, 1996) which, in the wild, are used as alarm calls. High-frequency sounds activate the amygdala more effectively than low-pitched sounds. People yelling at an animal may result in the animal becoming fearful and attempting to escape (Grandin, 1999).

Cattle have wide-angle vision that enables themselves to see predators while grazing. Vision is their dominant sense and is responsible for about half of the sensory information they receive from their surroundings. Their visual field is 330 degrees and they have binocular vision for a limited area in front of them (Moran and Doyle, 2015). This is where they will have the clearest vision and ability to judge depth or distance. In order to get the best vision, cattle will lower their head and face towards the stimulus they want to explore. They have also a small blind spot directly behind them. Therefore, it is recommended not to approach cattle through their blind spot, or at least people handling cattle should talk calmly to avoid animals being surprised.

Handlers acting during on-farm killing need to understand the flight zone (Figure 2; Grandin, 1999). The flight zone is the animal's safety zone, and its size varies depending on the animal's degree of wildness or tameness. When a person enters the flight zone, the animal will turn away. According to Grandin (1999), the size of the flight zone is determined by three factors, which are mainly related to animal characteristics: genetically determined traits (excitable vs. calm), amount of contact with people and the type of the contact with people (negative vs. positive) (Moran and Doyle, 2015; Simova et al., 2017). Therefore, moving and handling of animals by their owner or the person delivering care to them should be easier (if the quality of the contact is positive). When handled by an unknown person (e.g. during large-scale killing), the handler has to adapt its behaviour following the characteristics of the animal (e.g. calm and tame or wild and excited).

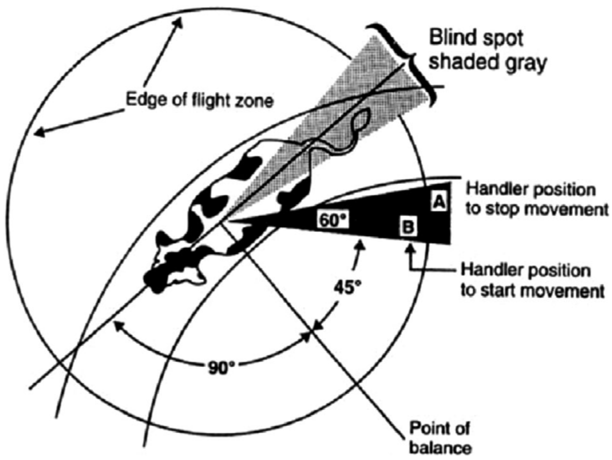

Figure 2: Flight zone and point of balance when handling cattle (Source: Temple Grandin website[16])

[16] https://www.grandin.com/ritual/euthanasia.slaughter.livestock.html

3.2.1. Welfare consequence 'Impeded movement': assessment, hazard identification and management

Definition of 'Impeded movement':

Difficulty of movement due to inappropriate floors resulting in slipping and falling.

Animals not handled correctly or in poorly designed and maintained premises will experience impeded movement that can lead to pain when animals are slipping and falling.

ABMs for 'Impeded movement':

The assessment can be done by counting the number of slips and falls per animal. Definitions of slipping and falling are provided in Table 3.

Table 3: ABMs for the assessment of 'Impeded movement' during handling and moving of the animals to the killing point

ABM	Description	Welfare consequence
Falling	Loss of balance, in which part(s) of the body (beside legs) are in touch with the floor (Welfare Quality®, 2009)	Impeded movement
Slipping	Loss of balance, without (a part of) the body being in touch with the floor (Welfare Quality®, 2009)	Impeded movement

Hazards leading to 'Impeded movement'

The impairment of animal welfare at this stage can be mainly due to two hazards:

1) Improper design, construction and maintenance of the premises.
2) Inappropriate handling.

Improper design, construction and maintenance of the premises

If the raceway from the pen area to the killing point is not well designed (angle of the slope, type of floor etc.), constructed or maintained (slippery etc.), this could lead to impeded movement due to animals slipping or falling.

It is highly challenging to handle large animals safely when they are slipping on the floor or panicking because they are losing their footing. Slips and falls occur mostly when concrete floors are wet with rain, urine or manure and it occurs especially when cattle are running or turning. In any case, there should not be any steep inclination of the floor from the home pens to the killing area. But in case steep ramps are used, there is a risk of injury from both jumping, slipping and falling of animals (Sandstrom, 2009). It is considered inappropriate to use a ramp angle greater than 20° for calves or 26° for adult cattle (Faucitano and Pedernera, 2016).

If cattle slip and fall and are reluctant to move, it may increase inappropriate, rough handling, leading to additional fear and pain.

Inappropriate handling

It is considered inappropriate handling when people are forcing the animals to move too quickly or through raceways not adapted for them. Moving cattle in an inappropriate way may result in a greater incidence of slips and falls.

Inappropriate handling might cause animals rushing and getting scared and then slipping and falling during moving.

Prevention and correction of 'Impeded movement' and its related hazards

The preventing methods to avoid impeded movement are the following:

- Floors should be clean, dry and non-slippery.
- It is recommended to move cattle in small groups (ideally of familiar animals) using flags, a plastic bag on a stick, streamers or a plastic paddle in order to ease handling and reduce occurrence of slipping and falling (Grandin, 2008).
- Avoid right angles and too steep raceways (> 20° for calves or 26° for adult cattle) (Faucitano and Pedernera, 2016). When the slope is steeper than 10°, raceways should be equipped with foot battens or cleats which prevent animals from slipping while walking on the ramp, reducing

the risk of falls (EFSA AHAW Panel, 2011). A 20 cm spacing between the cleats is recommended to ease cattle walking smoothly through the ramp (Grandin, 2014).
- People involved in handling and moving and killing of animals at farm should have adequate knowledge and understanding of the species-specific behavioural patterns as well as skills to perform the tasks allocated to them.

As corrective measures, the first step in improving animal movement is to correct mistakes that people make while handling and/or moving animals. The corrective recommendations should be (Grandin, 1999; Faucitano and Pedernera, 2016): (i) use the flight zone and the point of balance principle, (ii) stop the use of electric goads and use moving aids described above, (iii) use following behaviour and move the cattle in small groups.

Stopping obvious handling mistakes will make it possible to determine if the problems when moving and handling animal in a particular farm are due to people making mistakes or to a default in the design and/or maintenance of the raceway. It might happen often on farm that the raceway is built in an emergency context and therefore is not adequate. In that case, using adapted handling methods for moving cattle with a low speed can help reducing impeded movement.

3.2.2. Welfare consequence 'Pain' and 'Fear': assessment, hazard identification and management

Definitions of 'Pain' and 'Fear':

Pain: An unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage (Raja et al., 2020).

Fear: Emotional state induced by the perception of a danger or a potential danger that threatens the integrity of the animal (Boissy, 1995).

Fear motivates animals to avoid predators and to survive in the wild. Fearful large animals, like cattle, are dangerous animals. They are more likely to injure themselves or the handlers than unfearful animals. In case animals are not used to human contact or had negative experiences with humans in the past, being moved and handled can generate fear to them. Cattle can become extremely fearful and agitated when they are suddenly exposed to a new experience, which can be the case when one is trying to move the animals in a specially built raceway or chute in order to take them to the killing point. Similarly, animals raised in extensive systems usually have few contacts with people and are difficult to handle (Gallo and Huertas, 2016). Such animals will react differently to those raised indoors or in frequent contact with humans and, therefore, gathering and moving them to the killing area may expose them to fear and eventually pain. There are also some structural deficiencies at farm level, mainly due to inadequate design and poor maintenance of handling structures (pens, corrals, races, crates, ramps and others), which can increase the probability of animals experiencing fear.

In case animals are already injured (and then not handled in a specific way adapted to their body status), slip and fall or are hit by the staff, they will be submitted to pain, that could even be boosted by fear.

ABMs for 'Pain' and 'Fear'*:*

ABMs for pain and fear are injuries, lameness, escape attempts, vocalisations, reluctance to move and turning around or moving backwards.

Slipping and falling (see Section 3.2.1) can lead to injuries, leading to pain. Injuries can, however, also originate from the rearing period.

Cattle vocalise when they experience something aversive or threatening, and therefore, it can be used as an ABM for fear (Grandin, 1998, 2001). Reluctance to move, turning around or moving backwards are also signs of fear (Sandstrom, 2009; Welfare Quality®, 2009).

Pain and/or fear can be assessed during handling and moving by counting the animals with injuries or lameness and the occurrence (per animal) of escape attempts, vocalisations, reluctance to move and turning around or moving backward (see Table 4).

Table 4: ABMs for the assessment of 'Pain' and 'Fear' during handling and moving of the animals

ABM	Description	Welfare consequence
Injuries	Tissue damage (bruises, scratches, broken bones, dislocations) (EFSA AHAW Panel, 2012a)	Pain
Escape attempts	Attempts to go through, under or over gates and other barriers. Head and neck stretched forward and either held level with back or slightly raised above or below back line (modified after Lanier et al., 2001)	Fear
Vocalisations	An animal's vocalising response in terms of mooing, bellowing or roaring (modified after Grandin, 2012). Frequently referred to as distress vocalisation in the literature	Pain, fear
Reluctance to move	An animal that refuses to move when coerced by the operator or that stops for at least 4 s not moving the body and the head (freezing) (adapted from Welfare Quality®, 2009)	Pain, fear
Turning around or moving backwards	When an animal facing towards the restraint area turns around or moves backwards (adapted from Welfare Quality®, 2009)	Fear

Hazards leading to 'Pain' and 'Fear'

The impairment of animal welfare at this stage can be mainly due to five hazards appearing either alone or combined:

1) Inappropriate design, construction and maintenance of premises
2) Inappropriate handling
3) Moving cattle from a group into a single line into the restraint
4) People entering the pen/rearing area
5) Unexpected loud noise

Inappropriate design, construction and maintenance of premises

Improper design, construction and maintenance of premises are major hazards, which may cause fear, and possibly pain. In a study in South America, Gallo and Huertas (2016) showed that problems are mainly due to structural deficiencies at farm level, and to inadequate design and poor maintenance of handling structures (pens, corrals, races, crates, loading ramps and others).

Handling problems due to hesitation and refusal of cattle to go forward can also be caused by for example poor lighting, distracting objects, such as moving chain, shining reflections off metal, sparkling water puddles, people up ahead, a coat hung on a fence, object on the ground, shadows, a change in flooring type or texture, a drain grate or air hissing (Grandin, 1996, 1999). If the raceway is not well designed (lighting, presence of shadows, distractions) or maintained, this could lead to fear and the reluctance of animals to move, and hence, the operator resorting to rough handling causing pain.

Inappropriate handling

Moving cattle in an inappropriate way that causes pain and/or fear results in balking, refusing to move forward, turning around or backing up in the raceway. When animals are acting in this way, employees are more likely to use force and harsh methods such as multiple shocks with electric goads to move them (Grandin, 2016).

Bad practices used to get the animals to move were reported by Gallo and Huertas (2016) to be common in South America, but they occur elsewhere on the globe. In certain situations, there is a tendency to use aggressive strategies to drive animals and inappropriate aids (sticks, goads, shouting and sometimes even unsuitable handling practices that are described by the OIE (2013)).

People entering the pen

People entering the house/pen is unavoidable and essential to handle and/or move animals. However, awareness of the species-specific behaviour of cattle (Grandin, 1996) may modify the behaviour of the handler and reduce fear (see section on handling above)

Unexpected loud noise

Defined as a noise that by its level and/or its suddenness induces fear in the animals.

Loud or distracting noises originate mainly from machines, gates clanging and from cattle and personnel shouting. Vocalisations of stressed cattle and human shouting, which is particularly abhorrent for animals (Weeks, 2008), are stressful. Excessive noise is one cause of animal agitation.

Prevention and correction of 'Pain' and 'Fear' and their related hazards

To prevent pain and fear related to moving and handling of cattle, it is advised to kill animals in or close to their home pen if possible. When deciding on the killing methods to be applied, this should be taken into consideration. This might include using firearms, when cattle are untamed and living extensively.

A long-term prevention should be for the farmer to train animals to be handled and moved.

When handling and moving the animals the handler needs to use the flight zone principle (see Figure 2) as well as the point of balance in order to avoid inappropriate handling. The point of balance is an imaginary line at the animal's shoulders. To induce the animal to move forward, the handler must be behind the point of balance. To make the animal move backward, the handler must be in front of the point of balance. Cattle will move forward when a handler walks past the point of balance in the opposite direction of desired movement (Figures 3 and 4).

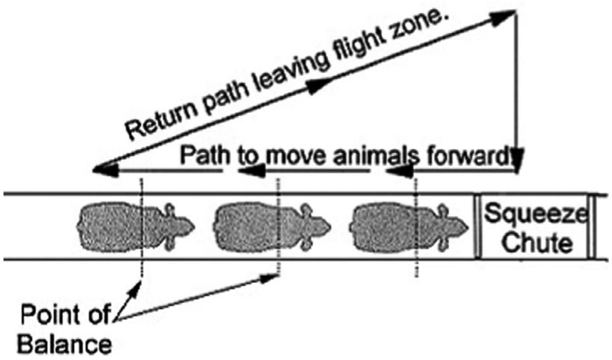

Figure 3: This movement pattern can be used to induce an animal to move into a squeeze chute or a raceway. The handler walks inside the flight zone in the opposite direction of desired movement (Grandin, 1999)

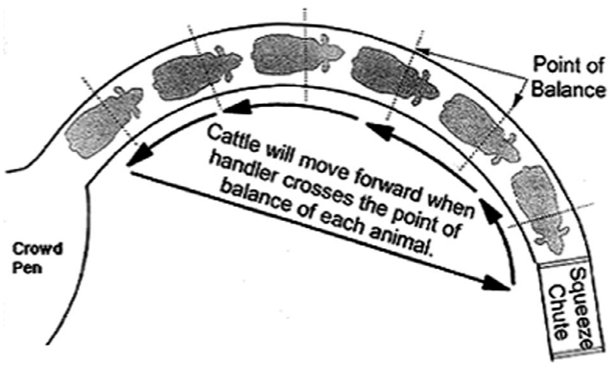

Figure 4: Handler movement pattern to use in a curved corridor or raceway system. The techniques here and in Figure 3 make it possible to avoid rough handling (Grandin, 1999)

Handling is safer when animals are moved quietly. Handlers should avoid yelling and flapping their arms, because this may agitate the animals. Use of electric goads increases animal agitation, as well as hazards to handlers and therefore should be avoided.

When people are entering the pen, attention should be paid so that the handler is not constantly invading the animal's flight zone (Grandin, 1999). The animals should have space to move away.

Constructing raceways with a minimum of distracting obstacles or factors will help to move animals at a normal speed without impeded movement, pain or fear. This is an example of using behavioural principles to control the animal, instead of force.

Attention should be paid to light, since animals may refuse to enter a dark place (Grandin, 1999). Use bright, diffuse lighting facilitates animal movement. Lamps can be used to attract animals into raceways and chutes, but the light should not glare directly into their eyes. When handling facilities are located inside a building, translucent plastic panels can be installed to admit diffuse, shadow-free light.

Distractions can cause animals to baulk and refuse to move when being handled and moved. In order to adapt the raceway configuration, it should be observed at a cow's eye height (Grandin, 1999). Some of the things to look for and remove prior to animals coming are (Grandin, 1996): moving chains, shining reflections off metal, sparkling water puddles, people up ahead, dripping water, a coat hung on a fence, objects on the ground, shadows, a change in flooring type or texture, a drain grate.

It is important to limit unexpected and intermittent loud noises, because they lead to fear and decrease coping capacities. It is especially important to reduce high-pitched noise. The preventive measures will consist in staff education and training (i) to make them aware that noise at the cattle's level should be avoided, and (ii) to make them avoid shouting and making noise with the equipment and facilities, and identify and eliminate the sources of noise. Facilities should be constructed to minimise noise. Pad gates with rubber stops to prevent clanging and banging can be used.

A first corrective measure is to correct mistakes that people make while handling and/or moving animals and that frighten the animals. The corrective measures would be (Grandin, 1999; Faucitano and Pedernera, 2016): (i) use the flight zone and the point of balance principle, (ii) stop the use of electric goads and use moving aids described above, (iii) use following behaviour and move the cattle in small groups instead of a single line or individually.

If an animal rears, people should back off and step out of the animal's flight zone. When people back away, the animal often settles back down. Handlers should never attempt to push a rearing animal; this is likely to increase its agitation and may cause an accident (Grandin, 1999). When cattle become agitated and fearful, up to 20 min is required for their heart rate to return to normal (Grandin, 1999). In case cattle gets agitated it should be given an opportunity to calm down before continuing handling and moving. It might happen often on farm that the raceway or chute is built in an emergency context and therefore is not adequate. In that case, using adapted handling methods for moving cattle with a low speed of moving can help reducing fear. In case of unexpected loud noise frightening the animal, personnel should suppress immediately the source of noise.

3.2.3. Outcome table on 'handling and moving' of cattle

Table 5: Outcome table on 'handling and moving of cattle'

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measure/ (implementation of SOP)	Corrective measure
People entering the pen/ rearing area	Fear	Staff	Requirement for the process	None (unavoidable as part of the method)	Minimise disturbance
Inappropriate handling	Pain, fear, impeded movement	Staff, facilities, equipment	Lack of skilled operators, operator fatigue, rushing, lack of dedicated handling facilities and restraint, time pressure, lack of appropriate driving aids	Training of staff for proper handling; staff rotation, appropriate equipment and facilities to move animals (e.g. temporary passage or race ways) Slow down the process	Take necessary action, use the balance point/flight zone concept to drive animals, act calmly
Unexpected loud noise	Fear	Staff, facilities, equipment	Staff shouting, machine noise, equipment noise	Staff training, avoid personal shouting, do not operate noisy machines and equipment in the animal handling area	Identify and eliminate the source of noise, stop shouting
Improper design, construction and maintenance of premises	Pain, fear, impeded movement	Staff, facilities	Inadequate preparation of the premises by staff; inappropriate lighting, distractions, improper construction (slope, slippery floor, angles, open-side raceways)	Ensure proper design, construction and maintenance of the area, ensure there are no distractions	Stop continuing movement of animals and take necessary action before resuming
ABMs: injuries (pain), vocalisations (pain, fear), escape attempts, reluctance to move, turning around or moving backwards (fear), slipping and falling (impeded movement)					

3.3. Phase 2 – Killing

3.3.1. Introduction

Several guidelines provide instructions to achieve effective killing (e.g. HSA, 2017; AVMA, 2019). On-farm killing should cause loss of consciousness followed by death without pain or fear. The killing phase includes both the restraint and the killing process. The killing of the animal can be performed by one step or two step methods. Restraint will be described in each method and 'restraint' means the application to an animal of any procedure designed to restrict its movements sparing any avoidable pain and minimising fear in order to facilitate effective killing.

3.3.1.1. Welfare consequences 'Pain and fear' and related ABMs

'Pain' and 'Fear' are defined in Section 3.2.2.

Cattle might experience pain and fear during restraining for killing, and therefore, the duration of restraint should be as short as possible. As a guide to good animal welfare practice, cattle should be restrained only when the operator is ready to kill the animal. ABMs related to pain during restraint are vocalisations, escape attempts and injuries. ABMs related to fear during restraint are escape attempts and vocalisations. For details, the ABMs related to restraint are described in full in Table 6.

Table 6: ABMs for the assessment of 'Pain' and 'Fear' related to restraint during killing of the animals

ABM	Description	Welfare consequence
Vocalisations	An animal's vocalising response in terms of mooing, bellowing or roaring (modified after Grandin, 2012). Frequently referred to as distress vocalisation in the literature	Pain, fear
Escape attempts	Attempts to go through, under or over gates and other barriers. Head and neck stretched forward and either slightly raised above back, slightly lowered or level with back (modified after Lanier et al., 2001)	Pain, fear
Injuries	Tissue damage (bruises, scratches, broken bones, dislocations) (EFSA AHAW Panel, 2012a)	Pain

Furthermore, ineffective stunning will lead to persistence of consciousness. Recovery of consciousness might also occur in effectively stunned animals if the animals are not dead or when a killing method is not performed in time or was not properly done. Both these situations will also cause pain and fear to animals and are considered an important animal welfare concern in the on-farm killing process.

Consciousness is defined as the capacity to receive, process and respond to information from internal and external environments and therefore the ability to feel emotions and being sensible to external stimuli, leading to pain and fear (Le Neindre et al., 2017).

Signs of consciousness are specific for each killing method (EFSA, 2004). ABMs related to consciousness are described in EFSA AHAW Panel (2013), which reports a toolbox for several killing methods.

Depending on the killing method, consciousness can be recognised by the failure to collapse or the absence of loss of posture, the absence of tonic–clonic seizures and the presence of normal breathing (including laboured breathing), and, in extreme cases, animals may also vocalise. Conscious animals and those recovering consciousness will show also spontaneous blinking or positive eye reflexes (palpebral, corneal and pupillary). Head righting (attempt to raise head) after stunning and body arching during bleeding are also signs of consciousness.

For each killing method flowcharts presenting the ABMs to recognise the presence of consciousness or life, are provided in the respective Sections.

In case of signs of consciousness or signs of life, an appropriate back-up stunning or killing method should be applied immediately (see Section 3.3.2.2) to mitigate the welfare consequences.

Death should be monitored and confirmed after applying the killing method and before disposal of the carcasses.

3.3.2. Penetrative captive bolt stunning followed by a second step killing method

Penetrative captive bolt stunning involves firing of a retractable bolt on the skull of the animal to induce brain concussion leading to immediate loss of consciousness.

In order to shoot the captive bolt in the correct position, the animals need to be restrained. Restraint can take place in fixed or mobile crushes and pens, or with chemical sedation (e.g. xylazine) (Gerritzen and Gibson, 2016).

There is limited guidance on specific methods of restraint for the different categories of animals (calves, cows, bulls) and other bovines such as buffalos (European Commission, 2017).

Restraint of cattle in a crush or a narrow pen allows easy access to the head with minimal discomfort for the animal. However, for some animals, the head needs also to be restrained for effective stunning (European Commission, 2017).

Most of the farms will have a cattle crush used for veterinary examination or weighing machine, and these can be modified to restrain for stunning and facilitate removal of unconscious animals after stunning. Cattle should not be restrained unless the operator is ready to apply the stunning method. If mechanical restraint is not available, cattle may be restrained using head halters with quick release knots.

Head collar and lead rope, halter or bridle are secured to restrict movement of the head. All halters, head collars used to restrain or handle cattle should be fitted with a method of quick release in case the animal becomes entangled in the equipment. These methods induce minimal discomfort for the animal and enable stabilising the head for stunning, including those cattle that cannot be moved from the pen or cannot rise, and need to be stunned where they are.

Young calves might be restrained manually by holding them against a wall or fence. However, this method can cause discomfort to the animal and might not be safe for the operator.

Calves are often fed from communal troughs where it is possible to stall and restrain them while feeding.

Penetrative captive bolt powered by cartridge is the most commonly used method to stun/kill cattle on farms (Shearer, 2018). The guns are designed to fire a retractable steel bolt that penetrates the cranium and enters the brain. The impact of the bolt on the skull results in brain concussion and immediate loss of consciousness (EFSA, 2004). Penetration of the bolt into the skull and subsequent withdrawal causes structural damage to the brain due to cavitation, which results in marked subarachnoid and intraventricular haemorrhages, especially adjacent to the entry wound and at the base of the brain. The bolt diameter and the strength, velocity and penetration depth are important parameters to ensure efficacy of the stun. If the diameter of the bolt is too narrow and sharp (like a nail), the bolt would easily penetrate through the skull and brain tissue without delivering the amount of kinetic energy required to inducing brain concussion. A thicker bolt (e.g. 7 mm) with blunt edge on the other hand would transfer more energy to the skull upon impact and also cause more severe structural damage to the brain during penetration and retraction. Existing recommendations on bolt velocities are based on abolition of evoked electrical activity in the brain: for steers, heifers and cows 55 m s^{-1} and for bulls 72 m s^{-1} (EFSA, 2004). The length of the bolt and thereby the penetration depth into the skull should be appropriate to the size of the cattle as recommended by the manufacturers. For example, Kline et al. (2019) investigated the effects of three different captive bolt lengths of 15.2 cm, 16.5 cm and 17.8 cm on the amount of brain tissue damage and hind limb kicking in cattle slaughterhouses. The air line pressure setting was 1,378.95–1,447.90 kPa for all captive bolts. Results of this study showed that all the test cattle ($n = 45$) were rendered immediately unconscious with a single shot; however, visual appraisal of the brains on the split heads indicated that the shortest bolt caused the least amount of brain damage. There was a trend ($p = 0.06$) for less kicking to occur when the 16.5 cm length bolt was used in the stunner. This finding is relevant to on-farm stunning also, as kicking could interfere/hinder with the application of a secondary killing procedure if required.

Some guns have a captive bolt that protrudes from the muzzle when it is in the primed position and some others have a bolt that is recessed within the muzzle. Normally, when a bolt is fired, it requires a short distance to reach its maximum velocity before impacting on the skull. Therefore, guns with protruding bolts should be held slightly (up to 5 mm) away from the animal's head, whereas guns with recessed bolts must always be pressed firmly against the head. Captive bolt length and power of cartridges should be selected according to the manufacturer's instruction to suit the size of the animal.

Various factors such as anatomical differences due to breed, sex or age of the animal, choice of the captive bolt gun and its maintenance, cartridge strength and its condition, shooting position and type of restraint used determine the effectiveness of stun. The ideal stunning position is in the middle of the forehead at the crossing point of two imaginary lines drawn between the eyes and the centre of the base of the opposite horns (HSA, 2016a).

The bolt parameters, i.e. velocity, exit length (depth of penetration into the skull) and diameter are determinants of the effectiveness of stun, i.e. depth of brain concussion. Ineffective stunning will occur due to low cartridge power, low bolt velocity, shallow penetration, too narrow bolt diameter and faulty equipment (EFSA, 2004). Minimum recommended bolt velocities are 55 m/s for steers, heifers and cows and 72 m/s for young bulls. Normally, recommended bolt diameter is a minimum of 7 mm and recommended penetration depth is at least 9 cm. Cartridges vary in strength and are classified according to the amount of propellant (gun powder) they contain, with 3.0 grain and 4.0 grain for large cattle and mature bulls (1 grain = 0.0648 grams). It is important to refer to the manufacturers' instructions so that the correct cartridges are used for each model of stunner; they are identified by calibre (0.22 or 0.25), colour and headstamp (HSA, 2016a). Captive bolt equipment powered by compressed air works exactly the same as the cartridge fired equipment, but the energy is supplied via a high-pressure compressor. The air line pressure may vary between 160 and 190 PSI (1,103.16 kpa and 1,310 kpa, respectively); higher pressures (1,448 kpa) have been reported in the literature (Martin et al., 2018; Kline et al., 2019). Most commercial slaughterhouses use a standard captive bolt length of 15.2 cm for pneumatic stunners in which only 9.02 cm of the bolt actually penetrates into the animal's skull (Kline et al., 2019). Longer bolts (16.5 cm and 17.8 cm) are used in order to induce more brain damage and increase the effectiveness of the stun but also increase the prevalence and intensity of post stun convulsions (Martin et al., 2018; Kline et al., 2019). Wagner et al., 2019 reported that the longer bolt length inflicted more visible damage to the brain. Oliveira et al., 2018 reported that pneumatically powered penetrating captive bolt resulted in immediate collapse, indicative of effective stunning, in 99% of cattle. Gibson et al. (2019) reported that shooting bulls with a pneumatic penetrating captive bolt was 100% effective on the basis of EEG parameters indicative of unconsciousness. In both these studies, an air line pressure of 220 psi (1,517 kPa) was used to fire the captive bolt gun.

Gilliam et al. (2014) reported that approximately 10% of animals required a secondary procedure to cause death. In that study, a single shot with penetrating captive bolt resulted in the death of 28/31 (90%), 17/19 (89.5%) and 8/10 (80%) adult, young and neonate, respectively. Specific reasons for the failure of penetrating captive bolt to cause death include insufficient depth of penetration of the bolt, differences in the resistance to bolt penetration related to hardness and thickness of the skin and skull and the potential for slight misdirection of the shot. Gilliam et al. (2012, 2014, 2018) also found notable differences between shot placement locations and breed characteristics.

Death may occur depending on the degree of injury to the brain, but is not a guaranteed outcome (Lambooij and Algers, 2016). Therefore, captive bolt stunning shall be followed as quickly as possible by bleeding and destruction of the brain and upper spinal cord by pithing or by a lethal injection.

Bleeding of cattle may be performed by severing the carotid arteries or brachiocephalic trunk. Delay in bleeding can occur when stunned animals convulse excessively, or when it is difficult to eject the animal from the restraint because of the position in which it has collapsed and it is lying in the restraint. Bleeding of captive bolt-stunned cattle will not be a preferred during killing for disease control and pithing with disposable rods is the best and reliable option (Appelt and Sperry, 2007).

Pithing involves inserting a flexible wire or polypropylene rod through the bolt hole in the head made by a penetrative captive bolt (Figure 5). The movement of the rod destroys the brainstem and upper spinal cord, ensuring death and reduces the reflex kicking (convulsions) which can occur after stunning. Size of the pithing rod should be appropriate to the size of the cattle, i.e. long enough to reach the upper spinal cord.

Inserting a pithing rod through the bolt hole and destruction of the neural tissue in unconscious animals causes convulsions that are aesthetically unpleasant and therefore educating the people who are not familiar with the physiology of stunning and pithing is vital to avoid misconceptions about the humaneness of the procedure or psychological trauma of the staff.

Figure 5: Illustration of pithing in cattle (source: Canadian Veterinary Medical Association)

Administration of a lethal injection is considered to be another secondary killing procedure that could be used to kill unconscious cattle after effective captive bolt stunning. In this regard, intravenous administration of an anaesthetic drug or saturated solution of potassium chloride may be used (AVMA, 2020).

Routine monitoring of the welfare outcome immediately after captive bolt stunning and pithing should be carried out using indicators presented in the flowchart (Figure 6). It is worth noting that heartbeat may continue for several minutes after effective pithing, and therefore, other indicators such as dilated pupils and absence of breathing may be used to assess the outcome immediately after pithing.

3.3.2.1. Hazard identification for 'Penetrative captive bolt stunning followed by a killing method' leading to 'Pain and fear'

The hazards identified during this process are:

1) Restraint
2) Incorrect shooting position
3) Incorrect captive bolt parameters
4) Overheating of the gun
5) Prolonged stun-to-kill interval
6) Incomplete sectioning of the blood vessels
7) Ineffective pithing
8) Sublethal dose of chemical
9) Disposal of cattle while alive

These hazards can lead to the welfare consequence of pain and fear and can lead to failure in onset of unconsciousness or recovery before death occurs.

Restraint

Limiting movements forward, backwards and sideways movements to restraint will carry the risk of pain and fear.

Incorrect shooting position

Firing a captive bolt away from the recommended shooting position leads to ineffective stunning and pain due to the impact of the bolt on the skull. When the shooting position is more than 2 cm from the ideal position, there is a greater risk of a shallow depth of concussion (Gregory et al., 2007). Captive bolt guns can be either trigger or contact fired. With contact fired guns, there is no possibility to correct the position of the gun once it touches the head of the animal. Incorrect position can be due to the lack of skilled operators or fatigue, poor restraint and wrong target area or angle of shooting.

Incorrect captive bolt parameters

The bolt parameters (velocity, exit length and diameter of the bolt) fail to effectively stun and render them immediately unconscious. It may be caused by e.g. low cartridge power, low bolt velocity, shallow penetration and faulty equipment (too narrow bolt diameter). If the bolt is too narrow, or the velocity is too low, there will not be enough energy transfer to the head to induce effective stunning (EFSA, 2004). The cartridges used should be those recommended for the equipment by the manufacturer (HSA, 2016a).

It has been shown that low charged cartridges produce less noise and that quieter discharges, when using the same grain cartridges stored under identical conditions, were associated with a lower depth of concussion and this can be used as an additional indicator of failed stun or shallow depth of concussion (Gregory et al., 2007).

Overheating of the captive bolt gun

Repeated firing of a captive bolt in quick succession will lead to overheating of its barrel and, as consequence, it will be difficult to hold and apply correctly, or the gun will cease to function properly. Therefore, captive bolt guns should be rested to cool and there should be enough guns available on site for this rotation to occur.

Prolonged stun-to-kill interval

The interval between captive bolt stunning and application of a killing procedure (i.e. intravenous injection of saturated solution of potassium chloride or overdose of anaesthetic drug, pithing or bleeding) is too long leading to cattle recovering consciousness and experience pain and fear.

Incomplete sectioning of the blood vessels

Failure to completely cut the carotid arteries or the brachiocephalic trunk that gives rise to carotid arteries will maintain blood supply to the brain and therefore lead to recovery of consciousness or delayed onset of death.

Ineffective pithing

Incomplete pithing fails to destroy the brainstem and upper spinal cord. It is ineffective as killing method as it leads to recovery of consciousness or delay in onset of death. This might occur when the rod is not long enough to destroy these areas of the brain or the direction of the movement with the rod does not target the deeper parts of the brain.

Sublethal dose of chemical

The concentration or dose of potassium chloride or of an anaesthetic drug administered to unconscious cattle is not adequate to kill, leading to recovery of consciousness or delayed onset of death.

Disposal of cattle while alive

Although the method is intended to kill the animals, there is always a risk that the animals are not dead due to insufficient application of the killing method. Lack of monitoring and confirmation of death can lead the disposal of live animals that may recover consciousness and be submitted to pain and fear.

3.3.2.2. Animal-based measures (ABMs) in the context of 'Penetrative captive bolt stunning followed by a killing method'

ABMs related to pain and fear during restraint are vocalisations and escape attempts, for definitions see Section 3.2.2.

ABMs related to pain and fear after the penetrative captive bolt stunning are related to the state of consciousness, since consciousness is a prerequisite for animals to be able to feel pain and fear. After the killing process, death should be ensured and any outcome of life will be interpreted as a possibility for cattle to recover consciousness and then be able to experience pain and fear. Therefore, ABMs of state of consciousness and state of death should be used to assess pain and fear in these specific conditions.

ABMs for the state of consciousness and death are specific for each killing method.

As retrieved from literature, the recommended ABMs for monitoring the state of consciousness and death after the captive bolt application are posture, breathing, tonic/clonic seizure, corneal or palpebral reflex, vocalisation and eyes movements.

For the assessment of the state of death after the application of the killing method (e.g. pithing, lethal injection or sticking), the recommended ABMs are: body movements, breathing, corneal or palpebral reflex, heartbeat and pupil size. These ABMs are phrased neutrally (e.g. breathing) and their corresponding outcomes will indicate either unconsciousness and absence of pain and fear (e.g. apnoea) or consciousness and risk of pain and fear (e.g. rhythmic breathing). The same rationale applies for the ABMs of the state of death and their corresponding outcomes of life or death.

The ABMs for the state consciousness and of death and their corresponding outcomes are described in detail in Table 7.

ABMs related to pain and fear after stunning are the measures to assess the state of consciousness.

Table 7: ABMs for the assessment of the state of consciousness and death after 'Penetrative captive bolt stunning followed by a killing method'

ABMs	Description
State of consciousness	
Posture	Effective stunning will result in immediate collapse or loss of posture in animals that are not restrained or prevented from doing so. Ineffectively stunned animals, on the other hand, will fail to collapse or will attempt to regain posture after collapse (EFSA AHAW Panel, 2013)
Rhythmic breathing	Effective stunning will result in immediate onset of apnoea (absence of breathing). Ineffectively stunned animals and those recovering consciousness will start to breathe in a pattern commonly referred to as rhythmic breathing, which may begin as regular gagging and involves respiratory cycle of inspiration and expiration. Rhythmic breathing can be recognised from the regular flank and/or mouth and nostrils movement. Recovery of breathing, if not visible through these movements, can be checked by holding a small mirror in front of the nostrils or mouth to look for the appearance of condensation due to expiration of moist air (EFSA AHAW Panel, 2013)
Tonic seizures	Effective stunning will result in tonic seizures manifested as an arched back and rigidly flexed legs under the body (EFSA AHAW Panel, 2013). Lack of occurrence of tonic seizures is indicative of consciousness
Palpebral and/or corneal reflex	The palpebral reflex is elicited by touching or tapping a finger on the inner/outer eye-canthus or eyelashes. Correctly stunned animals will not show a palpebral reflex. Ineffectively stunned animals and those recovering consciousness will blink in response to the stimulus. The corneal reflex is elicited by touching or tapping the cornea. Ineffectively stunned animals and those recovering consciousness will blink in response to the stimulus. Unconscious animals may also intermittently show a positive corneal reflex (EFSA AHAW Panel, 2013)
Vocalisations	Conscious animals may vocalise, and therefore purposeful vocalisation can be used to recognise ineffective stunning or recovery of consciousness after electrical stunning. However, not all conscious animals may vocalise (EFSA AHAW Panel, 2013)
Eye movements	Eye movements and the position of the eyeball can be recognised from close examination of eyes after stunning. Correctly stunned animals will show fixed eyes, and this can be recognised from wide open and glassy eyes with clearly visible iris/cornea in the middle. Eyeballs may be obscured in some animals owing to rotation into the eye socket following effective stunning. Ineffectively stunned animals and those recovering consciousness will show eye movements (EFSA AHAW Panel, 2013)
State of death	
Body movements	Complete and irreversible loss of muscle tone leads to relaxed body of the animal, which can be recognised from the limp carcass (EFSA AHAW Panel, 2013)
Breathing	Sustained absence of breathing is a sign of death (EFSA AHAW Panel, 2013)
Corneal or palpebral reflex	Sustained absence of response to palpebral and corneal stimuli is a sign of death (EFSA AHAW Panel, 2013)

ABMs	Description
Heartbeat	Absence of heartbeat (pulse measured by the contraction of the ventricles) (EFSA, 2004)
Pupil size	Dilated pupils (mydriasis) is an indicator of the onset of brain death (outcome of death), the assessment of which requires close examination of the eyes (EFSA AHAW Panel, 2013)

These ABMs were therefore included in the following flowchart for penetrative captive bolt stunning followed by pithing (Figure 6), including toolboxes of ABMs (blue box in the figure) to be used during on-farm killing. For each ABM, there are corresponding outcomes of consciousness and unconsciousness as well as corresponding outcomes of life and death. The indicators are not ranked based on sensitivity and specificity. In case cattle show any of the outcomes of consciousness then an intervention should be applied (i.e. a back-up method). After any reintervention, the monitoring of the state of consciousness, according to the flowchart, should be performed again. Only when the corresponding outcomes of unconsciousness are observed the process can continue to step two (after pithing, lethal injection or sticking).

Following step two, in case cattle show any of the outcomes of life, an intervention should be applied. If outcomes of death are observed, the animals can be processed further (disposal of cattle).

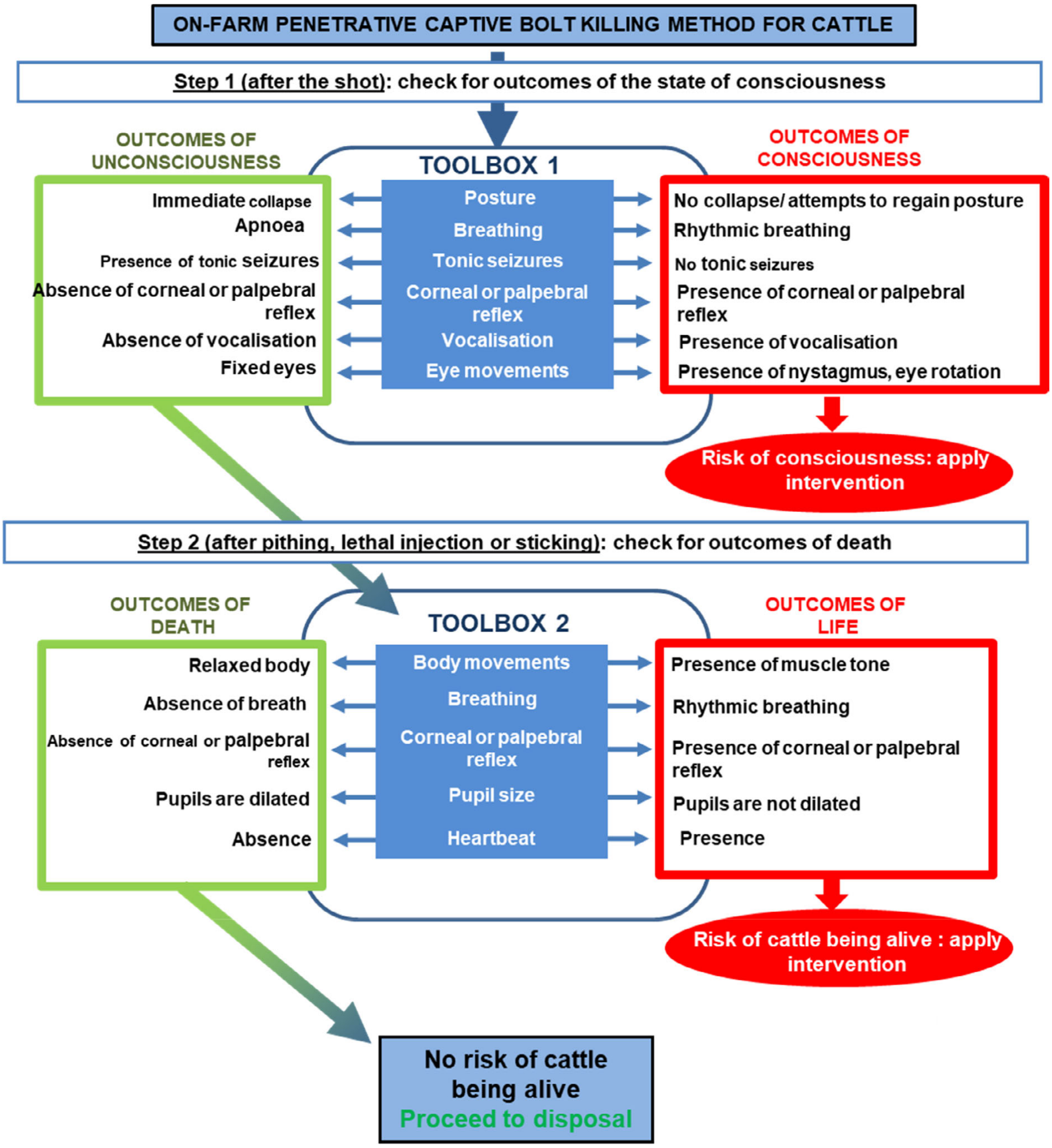

Figure 6: Flowchart including indicators for the monitoring of state of consciousness and death of cattle following penetrative captive bolt stunning

3.3.2.3. Prevention and correction of welfare consequences and their related hazards

Preventive measures for the hazards are:

A long-term prevention can be for the farmer to train animals to be restrained without the application of any negative stimulus before release. That will limit the risk of animals becoming fearful or struggling during restraint. Pain and fear during restraint and application of penetrative captive bolt stunning can be prevented through adequate design and maintenance of the restraining and stunning equipment and staff competence and training.

The restraint should suit the size of the animal. In the case of manual restraint, gentle handling of the cattle while they are restrained can minimise fear. Owing to this, duration of restraint should be as short as possible and, as a guide to good practice, animals should not be restrained until the operator (s) is ready to stun and pith, or bleed them or administer intravenous injection of saturated solution of potassium chloride or other lethal substances. Careful selection of people with adequate skills and the right attitude or giving training for them to acquire the skills appropriate to the tasks and relevant to cattle would help to minimise fear and pain in the animals being handled. Staff training, use of an appropriate restraint, proper placement and firing of the gun, and having equipment fit for the purpose are preventive measures.

It is also important to emphasise that cartridges must be stored in cool, dry place and damp and wet conditions should be avoided as it will lead to cartridges failing to fire or generate enough power to effectively drive the bolt. Captive bolt guns should be regularly cleaned and worn out buffers replaced to ensure the gun functions effectively.

A secondary procedure such as exsanguination, pithing or the intravenous injection of a saturated solution of potassium chloride (KCl) is highly recommended to ensure death whenever captive bolt is used (Gilliam et al., 2012, 2014, 2018; AVMA, 2013). Potassium chloride is cardiotoxic and when administered to unconscious animals by rapid intravenous injection it causes cardiac arrest.

Corrective measures for the hazards are:

After an ineffective shot, the mitigation measures are to re-stun as soon as possible in the correct position and direction, and with the correct parameters or with an alternative backup method (HSA, 2016a). When a captive bolt enters the skull, it causes massive damage and swelling around the wound; the swelling will absorb much of the impact of the second shot and this will mean the shock wave is not as effectively transmitted to the brain. Therefore, a repeat shot must always be placed so as to avoid the immediate area of the first shot. If the first shot is off target, the second should be placed as close to the correct stunning position as possible. If the first shot is on target but fails to produce an effective stun, the second shot should be above and to one side. If a third shot is required, this should be above and to the other side of the first shot.

Death should be ensured before carcass disposal.

3.3.2.4. Outcome table on 'Penetrative captive bolt stunning followed by a killing method'

Table 8: Outcome table on 'Penetrative Captive bolt stunning followed by a killing method'

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measure/s of hazards (implementation of SOP)	Corrective measure/s of the hazards
Restraint	Pain, fear	Staff, equipment	Immobilisation of the animal and presentation of the head of the cattle to the operator are required	Use passive head restraint or use optimum pressure according to the size of animal	Keep the duration of restraint to the minimum
Incorrect shooting position	Pain, fear	Staff	Lack of skilled operators, operator fatigue, poor restraint, wrong target area or angle of shooting, inappropriate placement of the gun due to the shape of the head	Staff training and rotation, appropriate restraint of the animal, proper placement of the gun	Stun in the correct position or apply a different killing method
Incorrect captive bolt parameters	Pain, fear	Staff, equipment	Lack of skilled operators, wrong choice of equipment, inappropriate cartridge and power, poor cleaning and maintenance of the equipment, too narrow bolt diameter, shallow penetration, low bolt velocity	Staff training, appropriate restraint of the animal, ensuring equipment is fit for the purpose, regular cleaning and maintenance of equipment	Stun with correct parameters and/or apply a different killing method
Overheating of the gun	Pain, fear	Staff	Lack of skilled operator, lack of sufficient number of captive bolt guns, lack of resting of captive bolt gun to cool	Staff training, ensuring sufficient number of captive bolt guns are available and rotation of captive bolt guns	None
Prolonged stun-to-kill interval	Pain, fear	Staff	Lack of skilled operators, too long time between stunning and killing	Staff training, prompt and accurate application of a killing method	Re-stun and apply a killing method
Incomplete sectioning of the blood vessels	Pain, fear	Staff, equipment	Lack of skilled operators, too short or blunt knife	Staff training, use of sharp knife long enough to cut the blood vessels	Re-cut if the animal is unconscious Re-stun before cutting again if the animal is conscious
Ineffective pithing	Pain, fear	Staff, equipment	Lack of skilled operator, inappropriate pithing rod	Training of staff, choice of pithing rod appropriate to the size of the animal	Apply pithing correctly
Sublethal dose of chemical used as a killing method	Pain, fear	Staff	Lack of skilled operator	Training of staff, ensure lethal dose of chemical	Apply lethal dose
Disposal of cattle while alive	Pain, fear	Staff	Lack of monitoring, too fast operation	Ensure death by proper monitoring of signs of life before disposal	Re-apply a killing method
ABMs: signs of consciousness (consciousness), signs of life (not dead), escape attempts (pain, fear), injuries (pain), vocalisations (pain, fear)					

3.3.3. Non-penetrative captive bolt followed by a killing method

Non-penetrative captive bolt stunning involves firing of retractable mushroom headed bolt on the skull of the animal to induce brain concussion leading to immediate loss of consciousness.

As in penetrative captive bolt stunning, this method also requires restraint (Section 3.3.2).

Non-penetrative captive bolts have a 'mushroom-headed' bolt tip, which impacts with the skull, but does not enter the brain. This type of equipment causes insensibility due to concussive forces alone. In adult cattle, the non-penetrative captive bolt should be positioned approximately 20 mm above the position used for the penetrative captive bolt and the animal must be killed immediately using a secondary procedure. Greater precision is needed to shoot an animal with a non-penetrating than with a penetrative captive bolt.

A potential welfare problem with stunning of cattle with a non-penetrative captive bolt is that it causes depressed fracture of skull bone at the site of impact and, as a consequence, some of the energy is absorbed and not entirely transferred to the brain, resulting in reduced efficacy (EFSA, 2004).

In the European Union, the use of a non-penetrative captive bolt is restricted to ruminants weighing less than 10 Kg (Reg. 1099/2009), thus limiting the use of non-penetrative captive bolts to small ruminants in the EU. However, it can be used on all ages/weight groups of cattle in other parts of the world. According to Shearer (2018), non-penetrative captive bolt may be used to stun/kill calves up to 3 months of age but details on effectiveness are not provided in this review. Gilliam et al. (2014) reported that 9/10 neonate calves were killed with a single shot. It is worth mentioning that the sutures of the skull bones in young calves would not have ossified fully, and therefore, it is advisable to fire non-penetrative captive bolts away from the sutures (EFSA, 2004). Bartz et al. (2015) investigated the impact of non-penetrative captive bolt stunning in 6–8 months old veal calves (n = 45). All calves were instantly rendered insensible by the initial stun and did not display indicators of return to consciousness.

In adult cattle, the skin covering the site of impact of the bolt on the skull may remain intact, but the skull bone underneath may suffer fracture. Owing to this, the impact energy may not be entirely transferred to the brain, leading to shallow depth of concussion or fail to stun the animal.

Oliveira et al. (2018) reported that pneumatically powered penetrating and non-penetrating captive bolts resulted in immediate collapse, indicative of effective stunning, in 99% and 91% of cattle (> 400 kg live weight), respectively. Gibson et al. (2019) reported that shooting bulls with a pneumatic penetrating captive bolt was 100% effective, whereas cattle shot with a non-penetrating bolt was effective in only 82% of cases, as assessed on the basis of EEG parameters indicative of unconsciousness. In both the studies, the non-penetrative captive bolts were powered by an air line pressure of 220 psi (1,517 kPa). Oliveira et al. (2018) found that the impact of the non-penetrative captive bolt produced extensive haemorrhaging around the cerebrum but did not cause any macroscopic lesions in the brainstem. However, Gibson et al. (2019) reported that effective stunning cattle (> 550 kg live weight) with the non-penetrative captive bolt resulted in rapid onset of an isoelectric EEG, but that non-penetrative captive bolt stunning was less effective than penetrative captive bolt stunning.

Collins et al. (2020) investigated the effects of stunning 4- to 5-month-old Holstein calves weighing between 100 and 200 kg, sedated with xylazine hydrochloride and some animals restrained using a head halter, with either a penetrating captive bolt (PCB; n = 6) or a non-penetrating captive bolt (NPCB; n = 6). In both the cases, the device (Cash Special captive bolt pistol, Accles and Shelvoke Ltd, Sutton Coldfield, UK; fired with a 0.25-calibre orange cartridge) was placed flush on the dorsal midline of the cranium at the external occipital protuberance and aimed downward towards the intermandibular area. Following stunning, indicators for loss of consciousness, such as respiration, righting response, corneal reflex, movement and vocalisation were recorded and characterised along with electrocardiograms (ECGs) and electroencephalograms (EEGs). After 5 min, a solution of potassium chloride (330 mg kg^{-1} or approximately 500 mL) administered intravenously until cessation of heart rate. Results showed that all the calves experienced immediate and sustained loss of consciousness based on immediate collapse, fixed eyes, absence of corneal reflex and absence of vocalisation or righting reflex. The mean (± SEM) time to cessation of respiration (apnoeic breaths or gagging) was 60 (± 53.67) and 0 (± 0.0) s for PCB and NPCB, respectively. The mean time to cessation of convulsions was 310.4 (± 79.74) and 180.0 (± 60.24) s, respectively, and the mean number of convulsions (movement of legs or kicking) was 2.75 (± 1.03) and 2.0 (± 0.837) for PCB and NPCB, respectively. Isoelectric EEG patterns were observed in 3/5 PCB and 3/4 NPCB with mean time to onset of isoelectric pattern in 69.0 (± 52.24) and 113.5 (± 56.87) s. Based on these results, the authors concluded that these techniques are appropriate for humane killing of calves until 4-5 months.

It is worth reporting that Bartz et al. (2015) investigated in a slaughterhouse the feasibility of stunning 33 calves with a non-penetrating captive bolt and immediately killing them by inducing cardiac arrest with an electric current applied across the chest. In this study, the calves (approximately 6–8 months of age) were stunned using a pneumatically operated nonpenetrating captive bolt (model USSS 2a; Jarvis Corp., Middletown, CT) fired with an air line pressure of 1310 kPa. Each calf was individually restrained in a restraint fitted with head restraint. Captive bolt stunner was applied on the frontal bones. The calves were ejected from the restraint immediately after captive bolt stunning and an electrical current was applied to the ribcage caudal to the shoulder joint while the stunned calf was in lateral recumbency. An electrical stunner (Compact Stun System; Applied Control Electronics, Greenville, PA) equipped with a forked stunning electrodes from a common head-only electrical stunner (model ES; Best and Donovan Corp., Cincinnati, OH) was programmed to deliver a regulated current of 2.0 amperes for 1 s by automatically adjusting output voltage (i.e. variable voltage constant current stunner) supplied with a frequency of 65 Hz. The calves were shackled, hoisted and bled out. The presence of consciousness was monitored, at 15 s post-stun after ejecting the animal from the restraint, at 45 s post-stun after shackling and hoisting and at 6 min post-stun (end of bleeding). The ABMs used in this study were: corneal reflex (eye-blink from touch), response to nose pinch with a needle nose pliers, rhythmic breathing, vocalisation and righting reflex. In addition, ECGs were recorded from 1-min post-stun and continued until after 4 min and 30 s during exsanguination. ECG traces were evaluated for the presence of QRS complexes, which appear as a result of myocardial depolarisation during ventricular contraction. The results indicated that stunning of calves with the non-penetrating captive bolt resulted in immediate onset and sustained unconsciousness. However, use of the above-mentioned electrical parameters was not entirely successful as 15.1% of the calves displayed QRS complexes in their ECGs, meaning cardiac arrest was not achieved.

It is therefore important to reiterate that effectively stunned animals have to be swiftly killed with a secondary procedure, i.e. bleeding by cutting the carotid arteries or brachiocephalic trunk, administration of intravenous injection of saturated solution of potassium chloride, or overdose of an anaesthetic drug using the route and dose as instructed by the manufacturer(s) (see Section 3.3.2).

Death should be ensured before carcass disposal.

3.3.3.1. Hazard identification for 'Non-Penetrative captive bolt killing method'

The hazards (excluding ineffective pithing) associated animal welfare consequences and ABMs are the same as for penetrative captive bolt stunning. (See Section 3.3.2.1).

3.3.3.2. Animal-based measures (ABMs) in the context of 'Non-penetrative captive bolt killing method

ABMs related to pain and fear during restraint are vocalisations and escape attempts (see definitions in 3.2.2).

ABMs related to pain and fear after the shot application are the signs of consciousness and death. The same signs of consciousness and death that are suggested for penetrative bolt killing were retrieved from the literature and therefore are suggested here for non-penetrative bolt killing method (see flowchart in Section 3.3.3.2).

3.3.3.3. Prevention and correction of welfare consequence and their related hazards

Preventive measures for the hazards are:

Pain and fear during the restraining and application of the non-penetrative captive bolt stunning can be prevented through adequate design and maintenance of the restraining and stunning equipment and staff competence and training. The restraint should suit the size of the animal.

In the case of manual restraint, gentle handling of the cattle while they are restrained can minimise fear. Owing to this, duration of restraint should be as short as possible and, as a guide to good practice, animals should not be restrained until the operator(s) is ready to stun and bleed them or administer intravenous injection of saturated solution of potassium chloride or an overdose of anaesthetic drug. Careful selection of people with adequate skills and the right attitude or giving training for them to acquire the skills appropriate to the tasks and relevant to cattle would help to minimise fear and pain in the animals being handled. Staff training, use of an appropriate restraint, proper placement and firing of the gun, equipment fit for the purpose and regular cleaning and maintenance of equipment according to manufacturer's instructions are preventive measures.

Corrective measures for the hazards are:

After an ineffective shot, the mitigation measures are addressed by re-stunning as soon as possible in the correct position and direction, and with the correct parameters or with an alternative backup method.

3.3.3.4. Outcome table on 'Non-Penetrative captive bolt stunning followed by a killing method'

Table 9: Outcome table on 'Non-Penetrative captive bolt stunning followed by a killing method'

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measure/s of hazards (implementation of SOP)	Corrective measure/s of the hazards
Restraint	Pain, fear	Staff, equipment	Lack of skilled operators, immobilisation of the animal and presentation of the head of the cattle to the operator are required	Careful selection of operators, staff training Use of passive head restraint or use optimum pressure according to the size of animal	Keep the duration of restraint to the minimum
Incorrect shooting position	Pain, fear	Staff	Lack of skilled operators, operator fatigue, poor restraint, wrong target area or angle of shooting, inappropriate placement of the gun due to the shape of the head	Staff training and rotation, appropriate restraint of the animal, proper placement of the gun	Stun in the correct position or apply a different killing method
Incorrect captive bolt parameters	Pain, fear	Staff, equipment	Lack of skilled operators, wrong choice of equipment, inappropriate cartridge and power, poor cleaning and maintenance of the equipment, too narrow bolt diameter, shallow penetration, low bolt velocity	Staff training, appropriate restraint of the animal, ensuring equipment is fit for the purpose, regular cleaning and maintenance of equipment	Stun with correct parameters and/or apply a different killing method
Overheating of the gun	Pain, fear	Staff	Lack of skilled operator, lack of sufficient number of captive bolt guns, lack of resting of captive bolt gun to cool	Staff training, ensuring sufficient number of captive bolt guns are available and rotation of captive bolt guns	Rest overheated captive bolt gun for the barrel to cool off
Prolonged stun-to-kill interval	Pain, fear	Staff	Lack of skilled operators, too long time between stunning and killing	Staff training, prompt and accurate application of a killing method	Re-stun and apply a killing method
Sublethal dose of chemical used as a killing method	Pain, fear	Staff	Lack of skilled operator	Training of staff, ensure lethal dose of chemical	Apply lethal dose
Disposal of cattle while alive	Pain, fear	Staff	Lack of monitoring, too fast operation	Ensure death by proper monitoring of signs of life before disposal	Re-apply a killing method
ABMs: signs of consciousness, attempt to regain posture (consciousness), signs of life (not dead), escape attempt (pain, fear), injuries (pain), vocalisations (pain, fear)					

3.3.4. Firearm with free projectile killing method

According to Regulation 1099/2009, firearms with free projectile – such as shotguns, rifles and humane killers – can be used to kill cattle, but national legislation may apply in terms of parties allowed to utilise firearms. A successful headshot causes immediate unconsciousness due to brain concussion upon impact of the projectile on the skull and death due to perforation of the projectile leading to extensive damage and destruction of the brain. There is no requirement for further bleeding or pithing of the animal. However, a secondary procedure will be necessary if the first and only shot failed to kill an animal.

Restraint is not necessary for this method, as cattle can be shot in the field using a trained marksman.

Animals can be lined up for shooting by scattering pelleted feed in a straight line facing the marksman. An elevated platform/hide/armrest can be constructed for the marksman (Retz et al., 2014), for example using straw bales, and facilitate accurate shooting.

In perfect placement of the shot, the projectile would penetrate the skull, immediately expand, travel through the brain case, obliterate the midbrain-brainstem and come to rest in the foramen ovale or the foramen of first or second cervical vertebrae (Whiting and Will, 2019). To ensure effective killing, it is recommended that animals are shot in the same position as for penetrative captive bolt, i.e. in the middle of the forehead at the crossing point of two imaginary lines drawn between the middle of each eye and the centre of the base of the opposite horn. This should give a position about 7 cm, ± 1 cm, above a line drawn across the forehead at the back of the eyes.

The most commonly used equipment includes (HSA, 2017):

- Humane killers (specifically manufactured/adapted, single-shot weapons and 'Bell Guns' of various calibres)
- Shotguns (12, 16, 20, 28 bore and .410)
- Rifles (0.22, 0.243, 0.270, 0.308)
- Handguns (various calibres from 0.32 to 0.45)

Humane killers are a purpose-made, single-shot weapon, which has a chamfered muzzle and vented barrel to facilitate its use with the muzzle end of the barrel in full contact with the target. However, in practice, some animals will move if contact is made. If this should happen, fire from as close as possible, preferably within 5 centimetres. To fire humane killers effectively some form of restraint is necessary (HSA, 2016b).

Shotgun is a long-barrelled, smooth-bore gun, normally used for discharging small shots at modest ranges. For farmed livestock species, a 12, 16 or 20 bore shotguns may be used with No. 4, 5 or 6 bird-shot; (a 28 bore or 0.410 can be used if nothing larger is available, but should not be used on mature bulls. The muzzle should be held from 5 to 25 cm from the animal's forehead, aiming down the line of the neck into the main bulk of the body. On no account must the muzzle of a shotgun be held directly against the animal's head, as this could result in a burst barrel and severe injury to the operator.

Rifle is a small bore, long-barrelled gun, usually fired from the shoulder, the bore of which has been scored with spiral grooves to impart spin on the bullet. The most common rifles in use on farms are general purpose 0.22 inch rim-fire, telescope sighted 0.22 inch centre-fire, 0.243 inch centre-fire and larger bore centre-fire weapons. The 0.22 inch rim-fire can be used effectively when loaded with the correct ammunition, to kill young cattle, when shooting from a short distance (from 5 to 25 cm away). However, they do have limitations in that there is no margin for error in respect of position and angle of incidence (HSA, 2016b). The larger calibre, centre-fire rifles are more specialised weapons used for long range shooting. They offer greater projectile velocities and subsequent kinetic energies than the common 0.22 inch rim- fire, and as such they do not fall into the categories of weapon which can be used at close quarters. These weapons can effectively kill all sizes of cattle, but they should only be used from a suitable distance, in an outdoor location with a safe backdrop, and by an expert marksman (HSA, 2016b).

Handgun is a small, short-barrelled, rifled firearm, which can be held and fired with one hand. There are two important points to remember when using a general-purpose handgun to humanely kill animals. First, the muzzle must never be placed in direct contact with the target: shoot from a distance of 5–25 cm and aim down the length of the neck into the main bulk of the body. Second, make sure that the ammunition is suitable for the task: most commercially available handgun ammunition is of the 'wadcutter' type and is loaded for target shooting. Although this type of ammunition is used occasionally for shooting animals, it is not suitable and it should be replaced immediately with round-nose, lead bullets.

In addition to the position and angulation of the shot, the projectile must have sufficient kinetic energy to ensure penetration of the skull to a level beyond the brain stem and sufficient damage to the brain, brain stem and upper spinal cord to produce concussion and instantaneous death. The ideal ammunition is one, which expands upon impact and dissipates its energy within the brain cavity (HSA, 2016b), causing destruction of the mid-brain and brain stem. According to the HSA (2016b) the ammunition should comply with the following criteria:

- Have a minimum calibre of 0.32 inches
- Generate a minimum muzzle energy of at least 200J
- Be round-nose, lead bullets to facilitate penetration and distortion

From the operator's safety point of view, it is advisable not to use an unnecessarily high velocity bullet that will exit the animal's head. On the other hand, the velocity must be sufficient to stun the animal. For bulls, a low velocity 0.44 bullet has been recommended, as the chance of it exiting the animal is less than a high velocity 0.303 or 0.27 bullets. Alternatively, bullets which fragment inside the skull could be used (Gregory, 2008).

Retz et al. (2014) investigated the effectiveness of shooting cattle in the field with four different calibres, two bullet types and two different shot placements. All of the calibres exhibited an entry-energy over 400 J and provided sufficient stunning potential. Yet, only calibre 0.22 Magnum caused no exit of the bullet out of the scull, which provides higher safety conditions for man and cattle. In this study, the shooter stood on a 4 m high platform and the distance between the muzzle of the gun and the skull of the animal was 15 m.

Effective concussion and destruction of the brain manifests as immediate collapse and onset of apnoea. Some animals might show severe tonic activity and others completely relaxed muscles (HSA, 2017). This period might be followed by a period of clonic convulsion with kicking movement. During this period, cattle do not show corneal reflex nor blinking. Ineffective or unsuccessful application can be recognised by the failure to collapse, the presence of breathing (including laboured breathing) and the absence of tonic and clonic seizure; in extreme cases, animals may also vocalise.

Individual animal needs to be examined to confirm death; any animal showing signs of life must be killed using a secondary procedure such as intravenous injection with overdose of an anaesthetic or lethal dose of saturated solution of potassium chloride.

The use of firearms in enclosed spaces, or when animals are on hard surfaces, could result in ricochet of free bullets and is to be avoided for health and safety reasons. The operators and bystanders must use extreme care in positioning of themselves and others when the procedure is performed. Another disadvantage is that in cases involving fractious animals, it may be difficult to get close enough to accurately hit the vital target area.

3.3.4.1. Hazard identification for 'Firearm with free projectile killing method'

1) Incorrect shooting position.
2) Inappropriate power and calibre of the cartridge.
3) Inappropriate type of projectile.
4) Disposal of cattle while alive.

The hazards identified related to the 'firearm with free projectile', relevant welfare consequences and related ABMs, origin of hazards, preventive and corrective measures are reported in Table 9.

<u>Incorrect shooting position</u>

Incorrect shooting position can occur due to bad weather conditions (wind) in the field, when shooting from a certain distance.

In addition, lack of skilled, operators, operator fatigue, wrong target area or angle of shooting and inappropriate placement of the gun due to the shape of the head can lead to incorrect shooting position. The animal should be stationary and in the correct position to enable accurate targeting.

<u>Inappropriate power and calibre of the cartridge</u>

Ineffective shooting might occur when the chosen firearm and projectile are inappropriate for the animal to cause immediate death. It can occur when using underpowered ammunition designed for use in target shooting, which therefore fails to penetrate; or to using metal-jacketed (metal sleeved) ammunition which over-penetrates without distorting enough to cause sufficient damage to the brain (HSA, 2016b).

Inappropriate type of projectile

Metal sleeved or jacketed high velocity bullets may exit the skull without causing destruction of the brain and therefore bullets that are designed and constructed to deform or fragment within the skull should be used.

Disposal of cattle while alive

Disposal of cattle alive can occur due to the lack of proper monitoring to confirm death in each animal.

Signs of death include dilated pupils, absence of heartbeat, absence of breathing and absence of muscle tone.

Animal showing signs of life must be shot again in the correct position using correct ammunition or lethal injection may be administered as a backup killing method, when animals are unconscious (AVMA, 2020).

3.3.4.2. ABMs in the context of 'Firearm with free projectile killing method'

ABMs related to pain and fear after application of firearm killing method are the signs of consciousness and death. The same signs of consciousness and death that are suggested for penetrative captive bolt stunning were retrieved from the literature and therefore are suggested here for firearm killing method (see ABMs in Section 3.3.2.2).

ABMs of an effective shot include (HSA, 2016b):

- Animal collapses immediately and stops breathing
- Carcase can be tonic or relaxed
- A fixed, glazed expression in the eye
- No corneal reflex
- Convulsions may occur after a lapse of up to 1 min.

3.3.4.3. Prevention and correction of welfare consequences and their related hazards

Preventive measures for the hazards are:

The use of appropriate firearm and ammunition are essential for preventing poor welfare outcomes. It is important to follow the manufacturer's instructions in terms of cleaning and maintenance of firearms, and choice of ammunition recommended for the type of cattle and shooting distance.

Furthermore, staff training can help to prevent incorrect position of the shot and inappropriate power, calibre of the cartridge and type of projectile.

Training of staff to use adequate procedures to monitor (un)consciousness will help to prevent and correct shooting failures. Inadequate shooting should be corrected by application of an adequate back up procedure.

Corrective measures for the hazards are:

Animals that are not killed by the shot should be re-shot or killed by using a secondary procedure, i.e. intravenous injection of saturated solution of potassium chloride or overdose of an anaesthetic drug.

3.3.4.4. Outcome table on 'Firearm with free projectile killing method'

Table 10: Outcome table on 'Firearm with free projectile killing method'

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measure/s of hazards (implementation of SOP)	Corrective measure/s of the hazards
Incorrect position of the shot	Pain, fear	Staff	Lack of skilled operator, operator fatigue, shooting in wrong place, animal moving	Staff training and rotation	Re-shoot the animal in the correct position
Inappropriate power and calibre of the cartridge	Pain, fear	Staff, equipment	Lack of skilled operator, wrong choice of equipment and cartridge, poor maintenance of the equipment	Staff training, appropriate equipment	Correct application of the power and calibre
Inappropriate type of projectile	Pain, fear	Staff, equipment	Lack of skilled operator, wrong choice of projectile	Staff training select a correct type of projectile	Apply another killing method
Disposal of cattle while alive	Pain, fear	Staff	Lack of monitoring, too fast operation	Staff training, Ensure death by proper monitoring of signs of life before disposal	Re-apply a killing method
ABMs: signs of consciousness (as a prerequisite for experiencing pain and fear), signs of life (as a prerequisite to recover consciousness)					

3.3.5. Electrical killing methods

Electrical killing involves application of a current of sufficient magnitude across the head and heart to induce unconsciousness and death.

Electrical killing methods require restraint. The principles of restraint are described in detail in Section 3.3.2 However, when restraining animals for electrical killing, it should be ensured that positioning of the electrodes on the head as well as on the chest (see below) is not hampered by the restraining device, e.g. a chute.

Electrocution of calves may be carried out using either a single current cycle applied head-to-body to induce simultaneously unconsciousness and cardiac arrest, or as a two current cycle method in which head-only stunning is performed to induce immediate unconsciousness immediately followed by a second current cycle applied across the chest to induce cardiac arrest. Von Mickwitz et al. (1989) even propose a three-cycle method, where applying current across the chest is again followed by head-to-head spanning of the brain to ensure unconsciousness before hypoxia-induced death.

Head-only stunning electrodes should span the brain and electrodes applied across the chest should span the heart. In the single current cycle method, the head electrode should be placed on the forehead and the body electrode should be placed at a position behind the anatomical location of the heart. A 50 Hz sine or square wave alternating current (AC) must be used in the single current cycle method and in the second current cycle applied across the chest to achieve effective killing as with a higher frequency of the current ventricular fibrillation is less likely to occur.

Blackmore and Peterson (1981) reported that head-to-leg application of 2 amps for 5 s produced cardiac arrest in 100% of 100 calves and application of 1 amp for 5 s with a head-to-back stunner induced cardiac arrest in 248 out of 250 calves. In both settings, two head electrodes spanned the brain, while cardiac arrest was simultaneously induced through the leg or back electrode.

Lambooij and Spanjaard (1982) evaluated cardiac arrest stunning in 6-month-old calves (average live weight 200 kg) using an equipment consisting of two flat metal prongs as head electrode and a saddle-shaped body electrode. Application of 0.8–1.0 A (50 Hz, 300 V or 600 V) for 1–2 s resulted in cardiac arrest in all the calves.

Von Mickwitz et al. (1989) used the above-mentioned three-cycle method also for killing of more than 300 adult cattle for disease control purposes. Head-to-head stunning for at least 20 s (2.5–3.0 A) is followed by spanning of the chest for at least 25 s (ventral/lateral; 1.8–2.8 A) and finally current is applied again head-to-head for 12 s (2.5–3.0 A).

According to Berghaus and Troeger (1998), a minimum current flow time of 0.3 s is necessary to induce epilepsy in the brain when head-only electrical stunning is applied with 1.3 A using a constant current stunner. The HSA (2016c) recommends a minimum current of 1.25 and 1.28 A for at least 3 s for head-only stunning and 1.25 and 1.25 A for 8–10 s for the chest application in calves and older cattle, respectively.

3.3.5.1. Hazard identification for 'Electrical killing'

Hazards leading to pain and fear identified during this process are:

1) Restraint
2) Wrong placement of the electrodes
3) Poor electrical contact
4) Too short exposure time
5) Inappropriate electrical parameters
6) Disposal of cattle while alive

<u>Restraint</u>:

Individual cattle may be restrained manually or mechanically in order to present its head to the operator for the purpose of correct application of head-only electrical stunning. Duration of restraint should be as short as possible and, as a guide to good practice, animals should not be restrained or restricted until the operator is ready to stun and kill them.

Too much force during restraining or when restricting the movement of animals can lead to pain and fear.

Wrong placement of the electrodes:

The position of the head electrodes does not span the brain to induce immediate unconsciousness or the second current cycle applied across the chest to induce cardiac arrest in unconscious animals does not span the heart.

If the head electrode is allowed to slide back onto the neck, the electrodes do not span the brain to induce unconsciousness. This could lead to painful induction of cardiac arrest in conscious animals.

Poor electrical contact:

The electrical contact between the animal and stunning electrodes is not sufficient to facilitate current flow necessary to achieve immediate loss of consciousness. Similarly, the electrical contact between the animal and chest electrodes is not sufficient to facilitate current flow necessary to achieve cardiac arrest and electrocution.

Too short exposure time:

For electrical killing methods, the duration of exposure to the electric current is too short to result in epileptiform activity in the brain and/or cardiac arrest resulting in death.

Inappropriate electrical parameters:

The electrical parameters (current, voltage and frequency) are not adequate to induce immediate loss of consciousness and/or death.

Several factors can contribute to this hazard (see Outcome Table 10). In particular, wrong choice of electrical parameters, too low applied voltages or current unable to overcome the electrical impedance/resistance in the pathway, use of electrical frequencies higher than 50 Hz, lack of calibration of equipment, lack of monitoring of stun quality and lack of adjustment to the settings to suit different types and sizes of animals.

Disposal of cattle while alive:

Although the method is intended to kill the animals, there is always a risk that the animals are not dead due to ineffective application of the killing method. Lack of monitoring and confirmation of death can lead the disposal of live animals.

3.3.5.2. Animal-based measures (ABMs) in the context of 'Electrical killing'

ABM's related to pain and fear during restraint and loading into restraining device are escape attempts, vocalisations, injuries, reluctance to move and turning back. For definitions, see Table 6 in Section 3.3.1.1.

ABMs related to pain and fear after stunning or killing application are the signs of consciousness.

The same signs of consciousness that are suggested for penetrative captive bolt killing (see ABMs's definitions in Table 7, Section 3.3.2.2) were retrieved from the scientific literature and are therefore suggested for electrical stunning.

Effective head-only electrical stunning of animals results in immediate collapse (when the animal's body is not supported by the restrainer), onset of tonic seizure during which the hind legs are flexed and forelegs extended, followed by clonic seizures manifested as paddling or kicking movements legs, breathing is absent during seizures and the eyeballs may be obscure, however, corneal and palpebral reflexes will be absent (Gregory, 1998; Grandin, 2020[17]).

Recovery of consciousness occurs following the resumption of breathing (Gregory, 1998). Ideally, the cardiac arrest current across the chest should be applied during the tonic seizure to avoid hindrance of leg kicking during clonic seizures. There can be a delay between the application of current across the chest and onset of effective cardiac arrest and animals should be closely monitored.

According to the AVMA (2020), when electrical methods are used, the following signs of return to consciousness must be absent: rhythmic breathing, righting reflex, vocalisation, eye-blink and tracking of a moving object.

Successful induction of cardiac arrest can be recognised from the signs of death, as with the other killing methods: absence of breathing, absence of corneal reflex, absence of muscle tone, dilated pupil, absence of heartbeat (pulse).

[17] http://grandin.com/humane/elec.stunning.cattle.html

These ABMs were therefore included in the following flowchart for electrical killing (Figure 7), including toolboxes of ABMs (blue box in the figure) to be used during on-farm killing. For each ABM, there are corresponding outcomes of consciousness and unconsciousness as well as corresponding outcomes of life and death. The indicators are not ranked based on sensitivity and specificity. In case cattle show any of the outcomes of consciousness an intervention should be applied (i.e. a back-up method). After any reintervention, the monitoring of the state of consciousness, according to the flowchart should be performed again. Only when the corresponding outcomes of unconsciousness are observed the process can continue to step two (after cardiac application).

Following step two, in case cattle show any of the outcomes of life, an intervention should be applied. If outcomes of death are observed, the animals can be processed further (disposal of cattle).

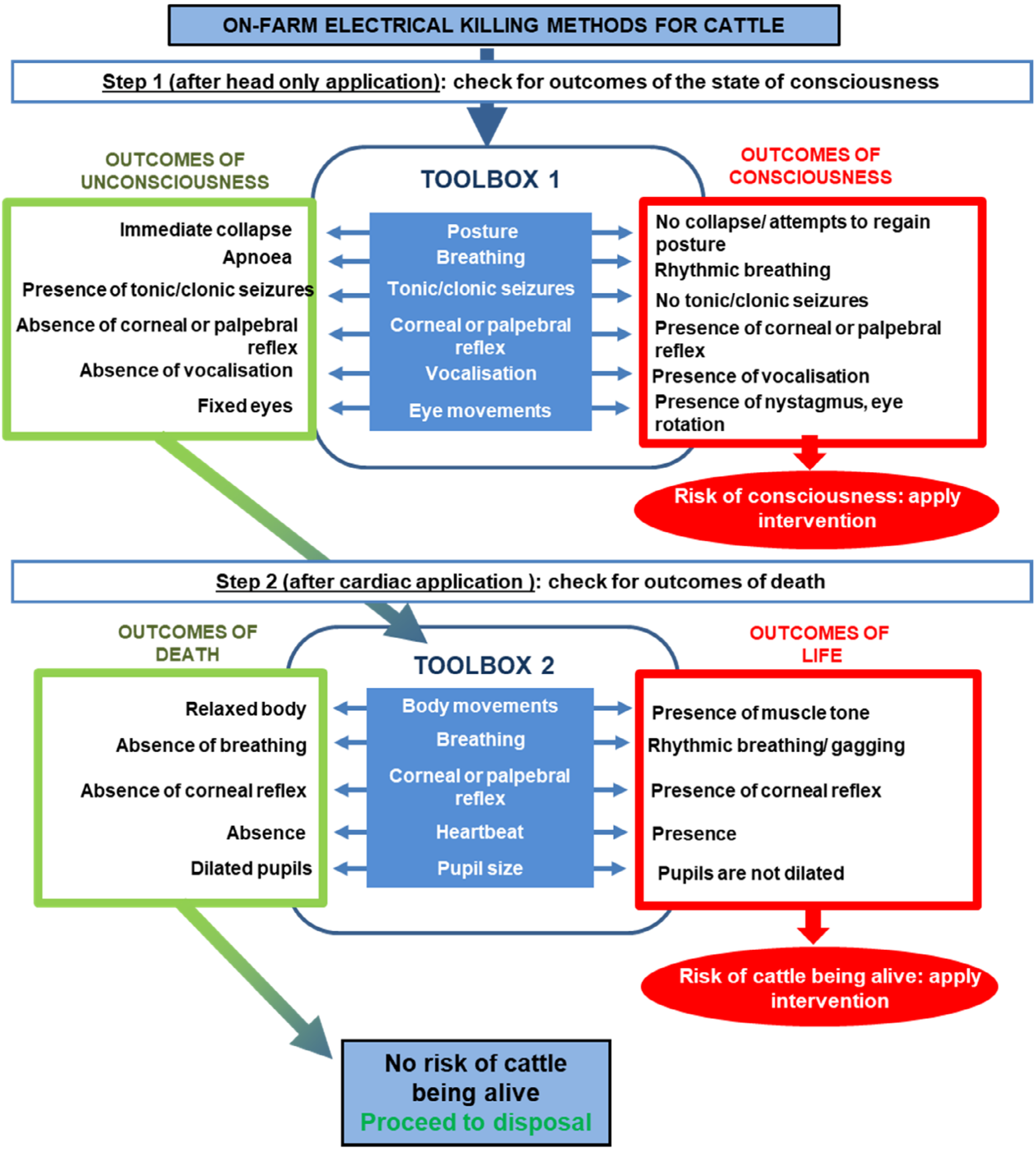

Figure 7: Flowchart including indicators for the monitoring of state of consciousness and death of cattle following electrical killing methods

3.3.5.3. Prevention and correction of welfare consequences and their related hazards

Preventive measures for the hazards are:

Pain and fear during restraint and application of head-only electrical stunning should be mitigated through adequate design and maintenance of the restraining and stunning equipment and staff competence and training. Staff should be trained to acquire adequate knowledge and skills to understand the behaviour of cattle and the need for optimum restraint required for stunning or adjusting restraint according to the size of the animal.

Animals must be restrained only when the stunning can be performed without any delay. Animals should not be left in restraint during work breaks, and in the event of a breakdown animals should be removed from the restraint promptly. The raceways and entrance to the restraint should not have sharp edges and should be always clean to maintain movement of animals without the need to use force and avoid animals slipping and falling (Grandin, 2012). The restraint should be adjusted to suit cattle of different sizes and weight range to minimise pain and fear. Duration of restraint should be as short as possible and, as a guide to good practice, animals should not be restrained until the operator (s) is ready to stun and bleed them. In addition, the width of the restraint should be appropriate for the size of the animals and loading of animals into the restraint should be done smoothly.

The electrical stunning device should be equipped with a built-in timer monitoring exposure time or visual or auditory warning system to alert the operator. It is recommended to deliver the current for a minimum of 3-s to produce adequate duration of unconsciousness that can persist until death occurs due to application of cardiac arrest.

Staff should be trained for correct placement of the stunning electrodes, maintaining adequate pressure, continuous contact between the animal and electrodes and use of current necessary to achieve effective stunning appropriate to the waveform and frequency. The operator should also have adequate knowledge, understanding and skills to recognise any variable (e.g. variation in the size of animal, dirt around the electrode contact area on the animal or build-up of dirt on the electrodes, malfunctioning of equipment) leading to wrong placement of electrodes or insufficient flow of current. Slowing down the process will help to prevent or minimise the incidence of some of the hazards, if high throughput is the cause.

Regular cleaning of electrodes using a wire brush, calibration and maintenances of the equipment are essential to prevent hazards that might lead to ineffective stunning.

Preventive measures for the hazards are:

Inadequate stunning should be corrected by application of an adequate back up procedure. For this purpose, staff should be trained to recognise signs of ineffective stunning by continuous monitoring and identify causes of failures such as high electrical resistance/impedance.

Regular auditing of the effectiveness of stunning by assessing the incidence of wrong electrode placement or the number of animals vocalising as consequence of poor placement will help to implement appropriate prevention/correction measures (Grandin, 2010).

3.3.5.4. Outcome table on 'Electrical killing'

Table 11: Outcome table on 'Electrical killing'

Hazard (see Section 3.3.2.1)	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measure/s for the hazard (implementation of SOP)	Corrective measure/s for the hazard
Restraint	Pain, fear	Staff	Presentation of cattle to the method is required	Use optimal restraint according to the size of the animal	None
Wrong placement of the electrodes	Pain, fear	Staff, equipment	Too fast operation, equipment does not suit the size of cattle Lack of skilled operator Improper or lack of restraint	Staff training Appropriate restraint Choose the right size equipment Slow down the process Choose the right size equipment	Stun using correct placement or use a back-up killing method
Poor electrical contact	Pain, fear	Staff, equipment	Lack of skilled operators, staff fatigue; incorrect placement of the electrodes; poorly designed, constructed and maintained equipment; intermittent contact	Staff training; staff rotation; ensure correct presentation of the cattle, ensure correct maintenance of the equipment; ensure the equipment includes electrodes for different sized animals; ensure continuous contact between the electrodes and the pigs; ensure regular calibration of equipment, regular cleaning of the electrode with a wire brush	Stun the animal correctly or use a back-up killing method
Too short exposure time	Pain, fear	Staff	Lack of skilled operators, too fast operation	Staff training Slow down the process ensure a timer is built in the stunner to monitor the time of exposure or use of a visual or auditory warning system to alert the operator	Stun using correct exposure time or use a back-up killing method

Hazard (see Section 3.3.2.1)	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measure/s for the hazard (implementation of SOP)	Corrective measure/s for the hazard
Inappropriate electrical parameters	Pain, fear	Staff, equipment	Wrong choice of electrical parameters or equipment; poor or lack of calibration; voltage/current applied is too low; frequency applied is too high for the amount of current delivered; lack of skilled operators, lack of monitoring of stun quality; lack of adjustments to the settings to meet the requirements Poor maintenance and cleaning of the equipment	Only use 50 Hz frequency sine wave alternating current, ensure the voltage is sufficient to deliver minimum current; regular calibration and maintenance/cleaning of the equipment; staff training; consider the factors contributing to high electrical resistance and minimise/eliminate the source of high resistance; monitor stun quality routinely and adjust the equipment accordingly; use constant current source equipment; use wire brush to clean tongs regularly	Stun using correct parameters or use a back-up killing method
Disposal of cattle while alive	Pain, fear	Staff	Lack of monitoring, too fast operation	Ensure death by proper monitoring of signs of life before disposal	Apply a killing method
ABMs: injuries (pain), vocalisations, escape attempts (pain, fear), signs of consciousness (as a prerequisite for experiencing pain and fear), signs of life (as a prerequisite to recover consciousness)					

3.3.6. Lethal injection as one step procedure

Overdose of an anaesthetic drug can be used as a sole method to kill cattle of all ages and weight groups.

As in penetrative captive bolt stunning, also lethal injection requires restraint, for details see Section 3.3.2. Attention should particularly be paid that restraint does not hamper access to the jugular veins.

Administered by intravenous injection, barbiturates induce a smooth transition from consciousness to unconsciousness and death by causing depression of the central nervous system and respiratory centres in the brain leading to cardiac arrest (Shearer, 2018). This method is used to kill sick and injured animals or as a secondary killing procedure in the field. The preferred route of administration is intravenous (HSA[18]; AVMA, 2020). Intracardiac administration can be extremely painful if penetration of the heart is not successful on the first attempt (EFSA, 2004). The intracardiac route may thus be used in previously anaesthetised animals only.

Other chemical agents such as T-61, a combination of embutramide, mebezonium iodide and tetracaine hydrochloride are used for killing cattle. However, the humaneness of this practice has been questioned. Concerns with T-61 include the potential for causing pain and irritation during rapid injection, and paralysis, which can result in the suppression of respiration prior to the onset of unconsciousness (EFSA, 2004). Because of these serious concerns, T-61 should be only used as killing method in unconscious cattle.

In addition, causing death by air embolism through intravenous injection of air or administration of a non-anaesthetic drug (as with xylazine or other alpha-2 agonist which is a sedative, analgesic and muscle relaxant) followed by intravenous injection of saturated solutions of potassium chloride or magnesium sulfate leads to serious welfare consequences (Shearer, 2018).

3.3.6.1. Hazard identification for 'Lethal injection as a one-step procedure'

The hazards leading to these welfare consequences are:

1) Restraint
2) Inappropriate route of administration
3) Sublethal dose
4) Disposal of cattle while alive

<u>Restraint</u>

Definition: Manual or mechanical restraint of animals to access a blood vessel. Chemical killing agents are often given with sedatives and/or anaesthetics (e.g. xylazine, ketamine), which physically restrain the animal to prevent injury to operators and improve the animal's welfare (Gerritzen and Gibson, 2016).

Moderate to severe restraint of animals is required for the purpose of IV injections. Individual cattle may be restrained in a standing position with a head halter.

<u>Inappropriate route of administration</u>

Definition: any route of administration different from the ones recommended by the manufacturer. This would include wrong route of administration and accidental spillage of drug from the intended route of administration.

<u>Sublethal dose</u>

Definition: use of a dose that is less than the one recommended by the manufacturer to kill cattle according to its weight.

Individual cattle may have to be weighed in order to calculate lethal dose, otherwise some animals will receive less than lethal dose required to causing rapid death.

<u>Disposal of cattle while alive</u>

Definition: disposal of cattle without confirmation of death.

Each animal should be examined carefully to confirm death.

[18] https://www.hsa.org.uk/lethal-injection/lethal-injection-1

3.3.6.2. Animal-based measures (ABMs) in the context of 'Lethal injection as a one-step procedure'

ABMs related to pain and fear during restraint are injuries, vocalisations and escape attempts.

ABMs related to pain and fear after application of the lethal injections are the ABMs of the state of consciousness. These ABMs of the state of consciousness are posture, breathing, corneal or palpebral reflex, vocalisation and eyes movements. At the end of the killing procedure, animals should be checked for signs of death to prevent that animals that are not dead are being disposed. These ABMs are the same as those described in previous killing methods (i.e. body movements, breathing, corneal/palpebral reflex, pupil size, heartbeat – see details in Section 3.3.3.2) can be used.

3.3.6.3. Prevention and correction of welfare consequences and their related hazards

Pain and fear during the restraining and application of the lethal injection can be prevented through adequate design and maintenance of the restraining equipment and staff competence and training. The restraint should suit the size of the animal.

In the case of manual restraint, gentle handling of the cattle while they are restrained can minimise fear. Owing to this, duration of restraint should be as short as possible and, as a guide to good practice, animals should not be restrained until the operator(s) is ready to administer intravenous injection of anaesthetic drug.

Preventive methods to avoid the above-described hazards and their welfare consequences are: follow the manufacturer's instructions, a preferential use of the intravenous (IV) route for injection, train staff to use appropriate restraint and presentation of the animal to avoid extravasation of the drug and use the correct dose according to the live weight of cattle. Corrective measures are use the recommended route of administration and inject the correct dose of drug to the animals.

To prevent the risk of discarding cattle alive, it is essential to examine individual animals for signs of consciousness or life and kill them humanely (corrective measures) by giving a lethal injection of an anaesthetic drug if they are conscious or of a lethal substance to kill them in case they are still alive but unconscious (see AVMA, 2020 for details).

3.3.6.4. Outcome table on 'Lethal injection'

Table 12: Outcome table on 'Lethal injection'

Hazard	Welfare consequence/s occurring to the cattle due to the hazard	Hazard origin/s	Hazard origin specification	Preventive measure/s of hazards (implementation of SOP)	Corrective measure/s of the hazards
Restraint	Pain, fear	Staff	Presentation of animal to the method is required	Use optimum restraint, if required, depending upon the route of administration	None
Inappropriate route of administration	Pain	Staff	Lack of skilled operators, inappropriate restraint, selection of wrong route of administration	Staff training, follow the manufacturer's instructions, use appropriate restraint	Adjust the route of administration
Sublethal dose	Fear	Staff	Administration of wrong dose of drug	Staff training, read the manufacturer's instructions to calculate dose appropriate to live weight	Re-inject with right amount of drug
Disposal of cattle while alive	Pain, fear,	Staff	Lack of monitoring, too fast operation	Ensure death by proper monitoring of signs of life before disposal	Apply a killing method
ABMs: injuries (pain), vocalisations (pain and fear), escape attempts (pain, fear,) signs of consciousness (as a prerequisite for experiencing pain and fear), signs of life (as a prerequisite to recover consciousness)					

3.4. Specific hazards and preventive measures related to selected types of animals or species

Some animals can be associated with some specific hazards related to their age, physical characteristics, breed or behaviour.

Pregnant cows

Based on the available scientific evidence, it cannot be determined with certainty whether livestock fetuses are capable of conscious perception. Using the available scientific literature and expert opinion, the EFSA AHAW Panel (2017) concluded on the capacity of livestock fetuses to experience pain and other negative affect using an approximate probability scale. The respective outcomes are summarised as follows: 1) It is very likely to extremely likely (i.e. with 90–100% likelihood derived from expert knowledge elicitation) that cattle fetuses in the last third of gestation have the anatomical and neurophysiological structures/correlates for experiencing pain and/or other forms of discomfort. 2) There are two different possibilities whether fetuses perceive negative affect. It is more probable that the neurophysiological situation does not allow for conscious perception (with 66–99% likelihood) because of brain inhibitory mechanisms. There is a lower probability that livestock fetuses can experience negative affect (with 1–33% likelihood) arising from differences in the interpretation of the fetal electroencephalogram, observed responses to external stimuli and the possibility of fetal learning. (3) Since all killing methods involve a maternal circulatory collapse and rapid fetal hypoxia, it is unlikely to very unlikely (i.e. with 1–33% likelihood) that changes/responses occurring during killing of the dam are associated with pain or other negative affect in the livestock fetuses (EFSA AHAW Panel, 2017).

Therefore, irrespective of the killing method used in the dam, the most critical aspect for fetuses of this developmental stage is the cessation of maternal circulation. Preventive actions for both the assumptions that livestock fetuses might or might not perceive pain or other negative affect (see point number 2 in the previous paragraph) are provided in Figure 8.

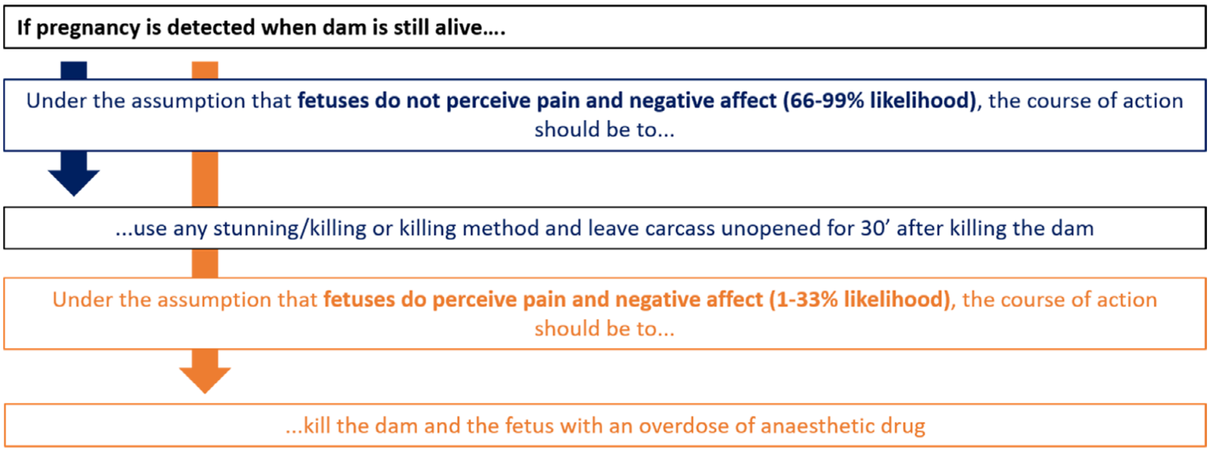

Figure 8: Courses of action as regards killing of dams in the last third of gestation and handling of the fetus under different assumptions regarding the neurophysiological situation of the fetus (modified after EFSA AHAW Panel, 2017).

Breeding bulls

Adult breeding bulls are generally much larger and heavier (> 1,000 kg) than cows (500–800 kg depending on breed) or finished beef cattle (450–750 kg depending on breed and production system). They require sufficiently sized passageways and killing boxes to allow for proper restraint and correct positioning of the killing devices. The bigger skulls and the larger thickness of the skull bones needs to be taken into account when selecting e.g. bolt diameter, bolt length and cartridge power in penetrative captive bolt stunning.

Extensively raised animals

According to Grandin (2014), extensively raised animals generally have an excitable temperament. Also, the level of human–animal interactions in e.g. pasture-based production systems can vary greatly.

This may impact on behaviour, complicate handling and increase the risk of fear reactions when such animals are exposed to humans and handling. To avoid fear and pain, restraint should therefore not be used when killing extensively raised, semi-wild animals, thus giving preference to firearm killing methods.

Buffaloes

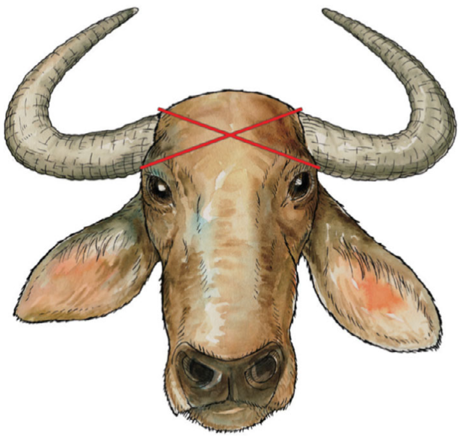

Figure 9: Preferred site for shooting water buffalo with firearms (source AVMA, 2020)

Passageways should be sufficiently wide, clean and not slippery (De la Cruz et al., 2018). Herding large buffaloes (> 600 kg) through narrow chutes designed for cattle has been shown to increase falls and collisions (De la Cruz-Cruz et al., 2014).

Shooting water buffaloes in the frontal position with a penetrative captive bolt is not always effective due to the massive frontal bones (Gregory, 2008); however, no prevalences for effectiveness of leading to unconsciousness are reported in the paper. Expert opinion is that mis-stunning occurs in the majority of cases when shooting in frontal position. The frontal and the paranasal sinuses are wider in buffaloes when compared with cattle (Saigal and Khatra, 1977); e.g. the median distance from the frontal skin surface to the inner bone table is 7.4 cm in water buffaloes and 3.6 cm in cattle, respectively. In addition, these anatomical features vary markedly with breed, sex and age of buffaloes. Schwenk et al. (2016) reported that even specially designed captive bolt guns with a protruding length of 12 cm may not be considered adequate to stun water buffaloes irrespective of age and sex in frontal position let alone conventional guns with a bolt length of only 9 cm. Provided that the energy delivered is adequate, however, the diencephalon might be reached with these devices when used in an occipital position. This is due to the fact that the average distance from the frontal or occipital shooting positions to the thalamus as the target region in the brain (including the skin) was 143 mm vs. 105 mm in frontal position for water buffaloes and cattle, respectively, and 106 mm in occipital position for water buffaloes (this distance was not measured in cattle as shooting in this position is not practiced). Corresponding maximum values were 172 mm vs. 121 mm in frontal position for water buffaloes and cattle, respectively (Schwenk et al., 2016). Thus, the use of penetrating bolts in occipital position with a protruding length of 12 cm might be considered to provide a solution to stun water buffaloes (Schwenk et al., 2016).

Gregory et al. (2009) evaluated the efficacy of different captive bolt stunning positions (frontal, crown and poll) in water buffaloes with different captive bolt gun/cartridge combinations. They reported that buffalo bulls over 30 months old had an average skull thickness at the frontal position of 8 cm and when these animals were shot in the frontal position, they did not collapse after the first shot. Shooting in the crown position, 16–19 cm from the foramen magnum, produced a shallow depth of concussion with continued respiration and eyeball rotation post-collapse in some animals. In contrast, shooting buffaloes in the occipital position, 1–4 cm from the foramen magnum (Figure 10), can produce an effective stun. However, the depth of concussion can be shallow, especially in animals aged over 30 months, of which 25% showed signs of rhythmic breathing that began slowly at about 38 s after shooting, indicating that a short stun-to-stick interval is crucial to prevent the animals from recovering consciousness. In buffaloes shot in the occipital position, 79% had damage to the cerebellum, and 71% to the medulla and/or pons.

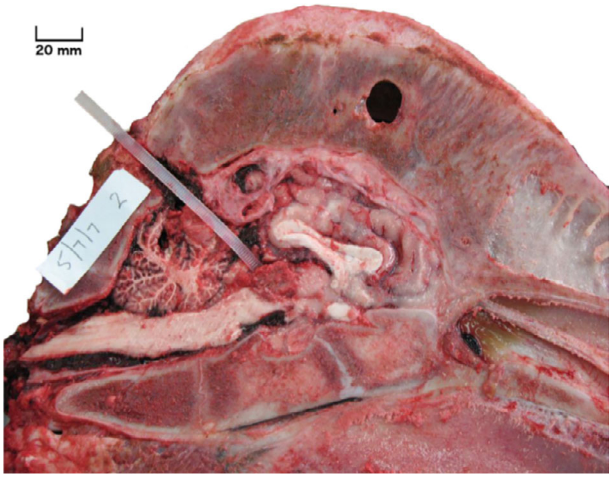

Figure 10: Example of a buffalo shot in the poll (occipital) position with the captive bolt entering into the occipital lobe and terminating in midbrain; about 10 cm travel of bolt and bone fragment. Left side: back of the head, right side: frontal direction (De la Cruz et al., 2018)

Nevertheless, the Humane Slaughter Association (HSA, 2018) has suggested that buffalo can be stunned in the occipital position using a heavy-duty contact-fired captive bolt gun fired using a minimum of 4 grain cartridge. The shot should be directed towards the nose, to direct the bolt through the cerebellum towards the mid-brain, by placing the muzzle of the captive bolt gun into the depression below the intercorneal protruberance and above the points of attachment of the Ligamenta nuchae.

When using firearms in buffaloes, the HSA (2018) recommends the ammunitions for killing of water buffalo and bison listed in Table 13.

Table 13: Type of firearm, ammunition and distance recommended for killing of water buffalo and bison (HSA, 2018)

Species	Slaughter site	Method	Distance
Buffalo	Field	243/.275/.308 rifle (JSP round)	10–30 metres whilst grazing
		12 bore shotgun (birdshot)	Close quarters*
	Slaughterhouse	12 bore shotgun (birdshot)	Close quarters*
		.32 humane killer/.38/.357 pistol	Close quarters*
Bison	Field	243/.275/.308 rifle (JSP round)	10–30 metres whilst grazing
	Slaughterhouse	.38/.357 carbine (semi-wadcutter)	1–2 metres whilst still in transport container

*: Space designed for aiming at the animal from a distance of a few metres and for protecting the operators' health and safety e.g. from a ricocheting bullet in the event of exiting the skull of an animal.

According to Glardon et al., 2018, bullet deformation has a strong impact on the outcome. Light 9 mm Luger or 0.38 Spl bullets as well as large deformable 0.44 Rem. Magnum bullets should be avoided in favour of heavier 0.357 Magnum deformation ammunition.

Bison

Bison are flightier and more fearful of humans compared with cattle. They show a larger flight zone, strong herd instincts and have a more aggressive nature (Grandin, 2007; Galbraith et al., 2014; Rioja-Lang et al., 2019). When animals are handled, alleyways should have limited side visibility and bison should be moved in small groups, as they become stressed and agitated when they have to wait in single files. This is also the reason why they should be brought up individually to the killing box. The killing box should have solid sides as well as a solid top to prevent bison from rearing and endangering workers (Lanier and Grandin[19]).

[19] www.grandin.com/behaviour/tips/buffalo.html

For animal welfare reasons, due to the thickness of the skull preventing proper stunning with a captive bolt, the recommended method for the euthanasia of a bison is gunshot (AVMA, 2020). A minimum of 1,356 J (1,000 feet-lb) of muzzle energy is required for euthanasia of yearlings, cows and mature bulls. This limits the firearm options to higher-calibre, centrefire rifles (e.g. 30- 30, 270, 30-06 calibre of the bullet). The majority of handguns produce muzzle energies well below 1,356 J (1,000 feet-lb) and would not be appropriate for euthanasia of mature bison. The preferred anatomic site for entry of a bullet is on the forehead (Figure 11), approximately 2.5 cm (1 inch) above an imaginary line connecting the bottom of the horns. Ideally, the angle of entry should be perpendicular to the skull. If it is necessary to shoot the animal from a distance, targets may be the head (frontal or lateral side) or the thorax (heart shot).

Figure 11: Preferred site for shooting bison with firearms (source: AVAMA, 2020)

3.5. Unacceptable methods, procedures or practices on welfare grounds

The mandate requests to identify unacceptable methods in terms of welfare. In this respect, the Panel agrees with OIE and EC Regulation 1099/2009 on unacceptable methods and practices.

EC Regulation 1099/2009 presents a list of methods of restraint that are prohibited. Some of these methods are related to cattle killing:

- suspending or hoisting conscious animals.
- mechanical clamping or tying of the legs or feet of animals.
- severing the spinal cord, such as using a puntilla or dagger.
- the use of electric currents to immobilise the animal that do not stun or kill it under controlled circumstances, and, in particular, any electric current application that does not span the brain.

Similarly, the Panel agrees with the principle in Chapter 7.5.10 of the OIE Terrestrial code (OIE, 2019), which says that 'methods and practices e.g. restraining methods [...] that cause severe pain and stress in animals, cannot be considered acceptable'.

In addition, the Panel has serious concerns about the following practices as they will induce severe welfare consequences:

- Moving severely injured cattle or those unable to move independently
- Use of painful stimuli to move animals (e.g. use of electric goads)
- Electrocution with low voltages, such as with a 120-volt electrical cord, insufficient to deliver the effective current to induce immediate loss of consciousness or death
- Painful induction of death in conscious animals (e.g. T-61, intracardiac administration of a drug, application of an electric current across the chest to induce cardiac arrest or sticking of conscious animals)

- Methods that do not induce unconsciousness but only tranquillise animals without killing them instead (deep tranquilisation as with xylazine or other alpha-2 agonist) followed by injection of saturated solutions of potassium chloride or magnesium sulfate

Furthermore, there are no documented scientific data on the effectiveness of a percussive blow to the head using a hard object such as a hammer, club or a metal pipe to induce unconsciousness. However, according to expert opinion, this method is prone to a high failure rate thus leading to severe welfare consequences.

These should be avoided, redesigned or replaced by other practices, which result in less severe welfare consequences.

In addition, most of the hazards originate from staff, and therefore, the Panel considers the lack of understanding or skills or lack of training of the staff working in the killing of cattle a serious concern.

Finally, the Panel is convinced that methods, which are likely to be highly painful, but have not been scientifically scrutinised, such as inflicting injuries and wounds leading to death, burying, drowning, suffocating, addition of pesticides or any other toxic substances to feed or water, injection of air as well as injection of chemical agents or other substances not specifically designed or labelled for euthanasia (i.e. disinfectants, cleaning solutions etc.) must never be used to kill cattle.

3.6. Assessment of uncertainty

Uncertainty related to the occurrence of false-positive and hazards false-negative was assessed (see methodology described in Section 2.2.4).

For evaluation of the risk of occurrence of false-positive hazards in the assessment, the experts elicited the probability that each hazard may exist during the on-farm killing process and should therefore be included in the outcome table (i.e. of being a true positive). For evaluation of the risk of occurrence of false-negative hazards in the assessment, the experts elicited the probability that at least one welfare-related hazard was missed in the outcome table.

Regarding the possible inclusion of false-positive hazards, the experts were 95–99% certain that all listed hazards exist during on-farm killing of cattle.

On the possible occurrence of false-negative hazards, the experts were 95–99% certain that at least one hazard was missing in the assessment considering the three criteria for the inclusion of methods and practices in this assessment and also considering the global perspective (i.e. including all possible variations to the slaughter practices that are employed in the world and that might be unknown to the experts of the WG). This is due to the lack of documented evidence on all possible variations in the processes and methods being practised (see Interpretation of ToRs on the criteria for selection of killing methods to be included).

4. Conclusions

This mandate requests EFSA to provide an independent view on the welfare of cattle including buffaloes and bison during killing on farm for purposes other than slaughter. This scientific opinion takes the common on-farm killing practices into account and focuses on the identification of hazards leading to negative animal welfare consequences during the on-farm killing. The hazards, their origins, preventive and corrective measures, welfare consequences and related animal-based measures (ABMs) were identified on the ground of literature search and expert opinion.

Not all the methods, procedures and practices for on-farm killing of cattle used worldwide are documented. Due to the lack of adequate description or scientific validation, a hazard analysis was not carried out for these methods, procedures or practices.

Outcome tables were prepared to summarise the main results of this scientific opinion and include a concise presentation of all retrieved information.

4.1. General Conclusions

1) During the on-farm killing processes, cattle may experience the negative welfare consequences pain, fear and impeded movement.
2) During the killing process, cattle may be exposed to multiple hazards, which could have a cumulative effect on welfare consequences (e.g. inappropriate handling and improper design, construction and maintenance of premises will have a cumulative effect and exacerbate pain and fear).

3) Some hazards may be present only during the phase of moving and handling, but the welfare consequence may persist during the killing phase until the animal is rendered unconscious (e.g. pain due to wounds resulting from inappropriate handling).
4) Some hazards are inherent to the killing method and cannot be avoided (e.g. restraint during lethal injection), while other hazards originate from suboptimal application of the method, mainly due to unskilled staff (e.g. inappropriate handling, use of wrong parameters in the case of electrical methods), and can be avoided.
5) Most of the hazards identified are associated with lack of skills and training (inappropriate handling) of the staff, and with poorly designed and constructed premises/facilities. The lack of skills or lack of training of the staff working during on-farm killing has a negative impact on the welfare of the animals and therefore the Panel considers this a serious concern.
6) The uncertainty analysis on the set of hazards for each process provided in this scientific opinion revealed that the experts were 95–99% certain that all listed hazards may occur during on-farm killing of cattle. At the same time, the experts were 95–99% certain that at least one welfare-related hazard is missing in this assessment considering the three criteria described in the Interpretation of ToRs (95–99% considering the worldwide situation). This is due to the lack of documented evidence on all possible variations in the processes and methods being practised.

4.2. Conclusions specific for Phase 1 – handling and moving

1) The identified welfare consequences during handling and moving are pain, fear and impeded movement. Corresponding ABMs are slipping and falling, escape attempts, vocalisation, injury, lameness, reluctance to move and turning around or moving backward.
2) Killing of cattle in their home pens and removal of carcasses would help to minimise hazards and their welfare consequences. When movement is unavoidable, limiting the distance of movement of live animals to the minimum would be beneficial to welfare.
3) Moving severely injured cattle or those unable to move unassisted will exacerbate their pain and is considered a serious welfare concern by the Panel.
4) The use of painful stimuli for handling and moving of the animals is considered a serious welfare concern by the Panel.

4.3. Conclusions specific to Phase 2 – killing

1) Consciousness is a prerequisite for cattle to experience pain and fear. Therefore, animals that are ineffectively stunned or recover consciousness will be exposed to the hazards and experience the related welfare consequences. Pain and fear can be assessed indirectly by assessing the state of consciousness by specific ABMs, which can be used at all steps.
2) Electrical and mechanical (excluding firearms) killing methods, and lethal injection require restraint that per se may impose additional pain and fear. These welfare consequences will persist during the restraining period until loss of consciousness.
3) Two-step killing methods involve stunning, which results in reversible loss of consciousness only, and the delayed application of a killing method increases the risk of recovery of consciousness.
4) The Panel has serious concerns about the following practices as they will induce severe welfare consequences:
   - The application of percussive blow to the head using a hard object such as metal pipes, sticks or a hammer;
   - Electrocution with low voltages, such as 120 volts, insufficient to deliver the effective current to induce immediate loss of consciousness or death;
   - Painful induction of death (e.g. T-61, intracardiac administration of a drug, application of an electric current across the chest to induce cardiac arrest or sticking of conscious animals).
5) In all age groups of cattle, non-penetrative captive bolt stunning is less effective than penetrative captive bolt stunning.

6) If killing is unsuccessful, cattle are subjected to the risk of being disposed alive and therefore recover consciousness with the possibility to be exposed to the hazards and related welfare consequences which are pain and fear.
7) In water buffaloes, captive bolt stunning in the frontal position is less effective than in the occipital position, due to the thickness of the frontal bones.

5. Recommendations

5.1. General recommendations

1) Design, construction and maintenance of the farm and handling facilities should be based on understanding how cattle perceive their environment and meet their welfare requirements (e.g. ease of movement) to prevent pain, fear and impeded movement before killing on farm.
2) Even with well-designed, constructed and maintained premises, training of staff is a key preventive measure to avoid hazards and mitigate welfare consequences: all processes of the killing should be carried out by trained and skilled personnel. Staff should be trained to consider cattle as sentient beings, to have a good understanding of species-specific behaviour and to act accordingly during all phases.
3) The welfare of cattle should be assessed at each phase of killing to prevent and correct hazards and mitigate negative welfare consequences.
4) When a hazard is identified, it should be corrected without any delay.
5) The presence of hazards should be monitored by assessing the welfare consequences through ABMs.
6) Farms should have SOPs which should include identification of hazards and related welfare consequences, using relevant ABMs, as well as preventive and corrective measures.
7) Practices which lead to serious welfare concerns listed in this scientific opinion should be banned, re-designed or replaced by other practices, leading to better welfare outcomes.
8) A ranking of the hazards according to the severity, magnitude and frequency of the welfare consequences for the cattle on-farm killing should be performed in a future scientific opinion.

5.2. Recommendations specific to phase 1 – handling and moving

1) Ideally, cattle should be killed in their home pens or pastures and carcasses moved for disposal. This especially applies to cattle that are injured, show severe pain, signs of illness or those unable to move without assistance.
2) If movement of cattle is required, the distance to the point of killing should be kept to a minimum and the animals should be moved gently.
3) Rushing the animals may cause fear, pain and impeded movement, animals being more difficult to handle subsequently (e.g. during restraint for killing). Animals should not be forced to move faster than their normal, unhindered walking pace.
4) Painful stimuli, such as electric goads, hitting with a stick etc. should be avoided. Instead passive stimuli such as flags, plastic paddles or streamers should be used.

5.3. Recommendations specific to phase 2 – killing

1) Animals should not be restrained if the operator is not ready to apply the killing method without any delay.
2) The use of non-penetrative captive bolt stunning should be avoided.
3) To monitor the efficacy of the killing method, the state of consciousness and death of the animals should be checked – i.e. after stunning, after the application of a killing procedure and before carcass disposal – using the suggested ABMs.
4) A back-up killing method should be readily available at any time to reduce the welfare consequences experienced by the animal and to put the animal to death without any delay.
5) Pithing of cattle stunned with a captive bolt must be performed without any delay after stunning. The pithing rod should be appropriate to the size of cattle and capable of destroying brain stem and upper spinal cord.
6) When a two-cycle electrical method is used to kill cattle on farm, the second current cycle should be applied during the tonic seizures that occur after the application of the first current cycle across the head.

7) Lethal injection of anaesthetic drugs should be performed strictly following the manufacturer's instructions in relation to dose, route and rate of administration.
8) Killing cattle with methods that are highly painful should not be used on welfare grounds. These include inflicting injuries and wounds leading to death, burying, drowning, suffocating, addition of pesticides or any other toxic substances to feed or water, injection of chemical agents or other substances not specifically designed or labelled for euthanasia (i.e. disinfectants, cleaning solutions etc.), air injection into blood vessels and deep tranquilisation as with xylazine or other alpha-2 agonist followed by potassium chloride or magnesium sulfate.
9) Water buffaloes should be stunned in the occipital position using a heavy-duty contact-fired captive bolt gun with a protruding length of at least 12 cm directed at the nose or using large-calibre firearms and deformation ammunition (e.g. 0.357 Magnum).
10) Bison should be killed using high-calibre, centrefire rifles (e.g. 0.30–30 winchester).
11) Animals that are difficult to handle should be killed *in situ* using firearms.

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Abbreviations

ABMs	animal-based measures
ECGs	electrocardiograms
EEGs	electroencephalograms
LS	literature search
NPCB	non-penetrating captive bolt
OIE	World Organisation for Animal Health
PCB	penetrating captive bolt
SOP	standard operating procedure
ToR	Term of Reference
WG	Working Group

Appendix A – Literature search outcomes

As described in Section 2.2.1, a literature search was carried out to identify peer-reviewed scientific evidence on the topic of 'killing of cattle' that could provide information on the elements requested by the ToRs, i.e.: description of the processes, identification of hazards, origins, preventive and corrective measures, welfare consequences and indicators.

To obtain this, firstly a broad LS under the framework of 'welfare of cattle at killing' was carried out, and the results were successively screened and refined as described below.

Sources of information included in the search: Bibliographic database 'Web of Science'.

The search string was designed to retrieve relevant documents to 'animal welfare' during 'slaughter and killing' of 'cattle'. Restrictions applied in the search string related to the processes characterising 'slaughter and killing' (from arrival to bleeding) of animals, and the date of publication (considering only those records published after EFSA, 2004). No language or document type restrictions were applied in the search string.

Date of the search: 7 December 2019

Web of science search string	
Years 2004–2019	
	Category
Search terms	**Field searched**
TS= cows OR TS=cow OR TS= cattle OR TS= calf OR TS= calv* OR TS= bull OR TS="bos taurus" OR TS= bovine*	Topic
AND	
TS=slaughter* OR TS=kill* OR TS=stun* OR TS=captive bolt OR TS=captive-bolt OR TS=euthanasia OR TS=depopulation	Topic
AND	
TS=Arriv* OR TS=*load* OR TS=lairage* OR TS=handl* OR TS=mov* OR TS=restrain* OR TS=cut* OR TS=bleed* OR TS=conscious* OR TS=pain* OR TS=behav* OR TS=stress*	Topic
AND	
TS="on farm" OR TS=on-farm	Topic
AND	
TS=Welf* OR TS="animal welfare"	Topic
TS="on farm" OR TS="on-farm" Topic	Topic
TS=reasons to kill OR TS=diseases OR TS=outbreaks OR TS=lameness OR TS=injuries	Topic
Results: 21	
Results after screening: 7	

Refinement of literature search results

The search yielded a total of 21 records that were exported to an EndNote library together with the relevant metadata (e.g. title, authors, abstract). Titles and abstracts were firstly screened to remove irrelevant publications (e.g. related to species, productive systems, processes and research purposes that were out of the scope of this scientific opinion) and duplicates, and successively to identify their relevance to the topic.

Full text publications were screened if title and abstract did not allow assessing the relevance of a paper. The screening was performed by one reviewer, with support by a second reviewer in cases of doubt; publications that were not considered relevant nor providing any additional value to address the question were also removed. The screening led to seven relevant records, which are reported in Table A.1.

Table A.1: List of publications relevant to 'Welfare of cattle during killing for purposes other than slaughter' resulting from the LS

ID	Reference
1	Farm Animal Welfare Committee (2018)
2	Gallo and Huertas (2016)
3	Gavinelli et al. (2014)
4	Grandin (2016)
5	Moran and Doyle (2015)
6	Shearer (2018)
7	Simova et al. (2017)